Interim Data Report

Man-Portable Simultaneous Magnetometer and Electromagnetic System

ESTCP Project MM-0414

AUGUST 2009

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SAIC

Environmental Security Technology Certification Program

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
AUG 2009		**00-00-2009 to 00-00-2009**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Man-Portable Simultaneous Magnetometer and Electromagnetic System	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Science Applications International Corporation (SAIC),1710 SAIC Drive ,McLean,VA,22102**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**116**	

Figure 1: MSEMS at SLO with interleaving hardware and RTK GPS receiver on backpack (on top of EM61 electronics box), and boom and 3rd wheel hosting magnetometer 4' in front of EM61 coil. GPS antenna and mag battery pack are mounted on boom.

Summary

From 4/29/2009 through 5/13/2009, MSEMS was used for the SLO Classification Study. As directed by the Program Office, 46 30m x 30m grids of concurrent magnetometer and EM61 MkII data were acquired. This document contains a description of the equipment used, how the data were collected, plots of static and calibration strip data, response curves over the calibration strip items, a description of the data processing and analysis methods, and images of the gridded EM61 MKII and total field magnetometer data acquired over the site.

Equipment

The Man-Portable Simultaneous EMI and Magnetometer System (MSEMS) developed under ESTCP Project MM-0414 consists of:

- A COTS Geonics EM61 MkII pulsed induction system with its stock coil, wheels, handle, backpack, battery, electronics box, and Allegro data logger
- A Geometrics 822 total field magnetometer suspended 4' in front of the edge of the EM61 coil on a carbon fiber boom supported by a 3rd wheel
- A backpack-mounted Man-Portable Interleaving (MPI) box that acquires magnetometer data between EM61 pulses
- An RTK GPS

- Custom software running on the Allegro that acquires magnetometer, EM61, and GPS data
- A battery pack for the magnetometer, GPS, and interleaving electronics

Since its successful ESTCP demonstration at YPG in 2006, MSEMS has undergone several important incremental improvements. In particular, certain modifications were made prior to the SLO deployment. These include:

- A new carbon-fiber boom was used that sits along the center line of the EM61 coil (the previous boom was offset creating a possible source of positioning error). Normally this is impossible because the EM61's terminal block is located along the center line of the coil and thus prevents center-mounting of a boom. For this reason, the EM61 coil was turned upside down so the coil block was located on the bottom, making the top of the coil free of obstructions and enabling the carbon fiber boom to be bolted along the center line of the coil.
- An EM61 MkIIA coil was employed. The MkIIA coil is potted (encapsulated in urethane) and has handle mounting hardware that is braced across the coil, making it considerably stronger than the unencapsulated MkII coil's handle mount that is clamped around one edge of the coil, potentially twisting the coil and causing cracking.
- The MSEMS data acquisition software was improved to timestamp the magnetometer and EM61 data in the industry-standard way for high-quality MEC geophysics – using an accurate, low-drift computer clock set to GPS time (previously MSEMS did not timestamp its data, instead relying on synchronization with the GPS' 1PPS and the acquisition of a fixed number of magnetometer and EM61 updates between 1PPS updates). This correct timestamping allowed the use of a real EM61 latency, instead of a "fudge factor" that simply lined up parts of anomalies.
- An inclinometer was affixed to the survey boom to measure platform pitch and roll. These data were recorded along with the magnetometer, EM61, and GPS data. Because the Program Office had already decided to slope-correct the data using a digital elevation model, these pitch and roll data were not used.

MSEMS Specifications

Magnetometer-to-EM61 Separation	4' for stock EM61 running at 75 Hz
Backpack	COTS EM61 MkII backpack. MPI box mounts directly over EM61 box.
Sensor Platform	COTS EM61 MKIIA coil mounted upside down. COTS EM61 MKIIA wheels, handle, and Allegro mount. Custom carbon fiber boom, 3rd wheel, gimbled magnetometer mount, and battery box.
Magnetometers	Up to two Geometrics 822 cesium vapor total field magnetometers with Larmor output.
Man-Portable Interface	SAIC's custom Mag Period Counter (developed under

(MPI)	ESTCP Project UX-0208) that interleaves magnetometer data between EM61 pulses. Constructed in an EM61 box that uses the same through-holes for backpack mounting.
Magnetometer Height	Bottom of sensor head measured as 17.5" above ground. Factoring in 2.4" offset from bottom to absorption cell yields effective height of 19.9".
Magnetometer Sampling Rate	75 Hz interleaved between EM61 pulses (samples magnetometer for 5ms before next EM pulse)
EM61 Configuration	Up to two Geonics EM61 MkIIs (4 time gates) driving 1 x ½ meter coil (lower coil only; long axis cross-track)
EM61 Sensor Height	COTS MkIIA coil and wheels measured as 15.5" to the bottom of the coil.
EM61 Sampling Rate	COTS 75 Hz pulse repetition rate (10 Hz serial output)
GPS	Trimble RTK with 1PPS output. 10Hz GGK output. GPS antenna halfway between magnetometer and edge of EM61 coil.
GPS-Magnetometer Synchronization	If 1 PPS is present, magnetometer is triggered by GPS 1 PPS signal, guaranteeing acquisition of correctly synchronized data
PDA and Software	Standard EM61 Allegro Juniper PDA with custom MSEMS software

Data Collection Methodology

The base GPS was set up over a known control point every morning. MSEMS was run over the calibration strip every morning to verify correct operation of the sensors. The responses from the magnetometer and EM61 calibration strip data were analyzed and appended to a spreadsheet that kept track of the responses of each object over the course of the survey. Survey grids were generally acquired in pairs (two 30x30m grids creating one 60x30m grid). Survey direction was north-south or east-west depending on which direction was more along the hill rather than up and down the hill. Line spacing was 0.5 meter. Down-track data spacing resulting from standard EM61 slow walking pace (approximate 1 meter/second) was approximately 10 cm for the 10Hz EM61 data and approximately 1.3 cm for the 75Hz magnetometer data.

Equipment Operation

The MSEMS equipment was operated by a two-person crew from NAEVA Geophysics (Ben Dammeron and Ivy Carpenter). Rob Siegel from SAIC was on-site at all times to provide technical assistance. This was necessary only once when the Allegro's memory card filled up and the source of the error was unclear; otherwise NAEVA prosecuted the survey completely autonomously.

MSEMS was operated essentially like an EM61, with the following minor procedural modifications:

- Though an EM61 or MSEMS can be either pushed or pulled (and is usually pulled when terrain is rough), for the SLO survey the system was only pushed in order to

ensure that the sensors were on the appropriate survey line and to collect the highest quality data.

- Because MSEMS uses a single GPS antenna to geospatially locate both the magnetometer and the EM61 coil, it is important that the system is lined up correctly at the start of each survey line. Since there is a four-foot boom and a 3rd wheel, this requires slightly more care than with a COTS EM61 which is simply spun around in place. For this reason, the system is paused at the end of each survey line, positioned at the start of the new line, then un-paused. The turnarounds are not captured in the data.

Other than these caveats, NAEVA collected the MSEMS data in the same way, and at the same rate, as they collected COTS EM61 data. Generally, two 30-meter grids were surveyed at a time. The resulting 60m x 30m area had tape measures emplaced at the ends, and a rope was moved ½ meter at a time to mark the line to be followed. NAEVA generally collected one pair of grids before and after lunch.

Survey Schedule

Static data and calibration strip data was acquired at the beginning and end of each day.

Monday 4/27/2009	Arrived on site, assembled equipment; set up GPS base station; trained NAEVA personnel in the operation of MSEMS; acquired training pit data
Tuesday 4/28/2009	Grids K8-L8 and K9-L9
Wednesday 4/29/2009	Grids M8-N8 and M9-L9
Thursday 4/30/2009	Grids O8-O9 and P9
Friday 5/1/2009	Grids N10-N11 and O10-O11
Monday 5/4/2009	Grids O12 and P10-P11; redo of training pit
Tuesday 5/5/2009	Grids M13-M14 and N12-N13
Wednesday 5/6/2009	Grids K13-K14 and L13-L14
Thursday 5/7/2009	Grids I12-J12, J13, and L15
Friday 5/8/2009	Grids H10-H11 and I10-I11
Monday 5/11/2009	Grids F10-F11 and G10-G11
Tuesday 5/12/2009	Grids I5 and J5-K5
Wednesday 5/13/2009	Grids J4-K4 and L5-M5

Data Processing Steps

Positioning: GPS data are viewed and corrected as necessary to fix jumps that come from non-RTK solutions. There were very few of these at SLO.

Magnetometer Data: The magnetometer data are positioned using the GPS projected forward two feet along the system's heading. They are then lightly median-filtered to remove spikes, notch-filtered to remove the 15 Hz sine wave that comes from the 60 Hz ambient electrical hum from the power grid that, due to the system's 75 Hz sampling, aliases at 15 Hz. The data were then read into Geosoft Oasis Montaj and background-leveled using a median filter 60 seconds long, ignoring 30% of lowest values and 30% of highest values. Note that the act of acquiring magnetometer data in an interleaved fashion

between EM61 pulses (period-counting the magnetometer for 5ms before the next EM61 pulse) restricts the accuracy of the period counting to between 0.5 and 1 nT. In order to keep acquired file sizes small, mag data are stored as integers, thus quantizing the data to 1nT precision (after the SLO survey, this was changed; MSEMS now stores data as floating point number). The filtering steps above output the data as floating point numbers.

EM61 Data: The EM61 data, as described above, are positioned using the GPS projected backward two feet plus the distance from the outer edge of the coil to the center of the coil. Data were latency-corrected using a latency value of 0.373 seconds. This value was determined by running over the calibration strip in both directions, taking the six strongest anomalies, varying the latency from 0.30 to 0.40 seconds in steps of 0.01 seconds, finding the best latency for each of the six objects, and then averaging the results. The data were then read into Geosoft Oasis Montaj and background-leveled using a median filter 60 seconds long, ignoring 10% of lowest values and 30% of highest values.

Secondary Analysis

Detection thresholds were determined by Nagi. Khadr, working in support of the Program Office, using modeled response curves. A threshold of 7.2mV on gate2 of the EM61 MKII was determined using the response curve for the 2.36" rocket. 7.2 mV is the expected signal strength at a depth of 45 cm; this uses a 50% margin on the depth of interest. The 2.36" rocket was used since it represented the lowest value of the response curves for all of the objects on the calibration strip.

Target analysis was performed by Mr. Khadr working in support of this project. Targets above 7.2mV threshold were extracted from the background-leveled EM61 MkII gate2 data using the Blakeley Test in Geosoft Oasis Montaj. The UxAnalyze module was then used to inverse-model the data to refine the target's location estimates.

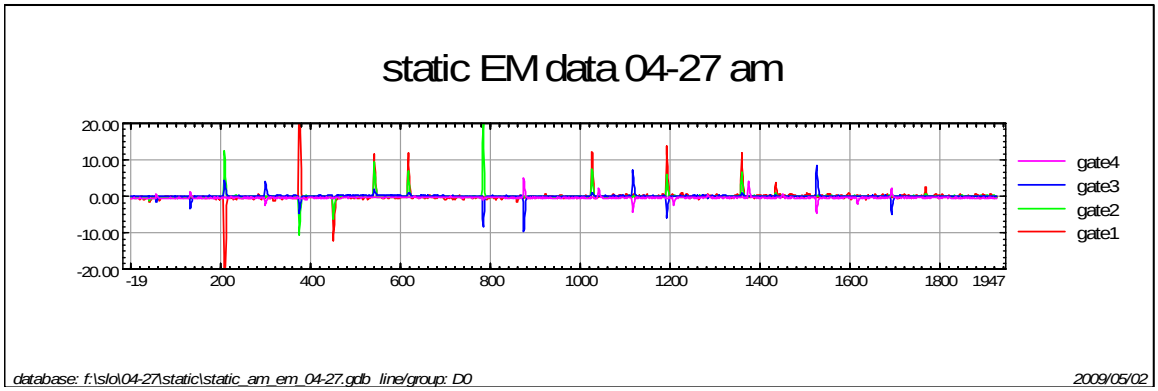
Target thresholds were determined for magnetometer data and targets were extracted from magnetometer data a similar way.

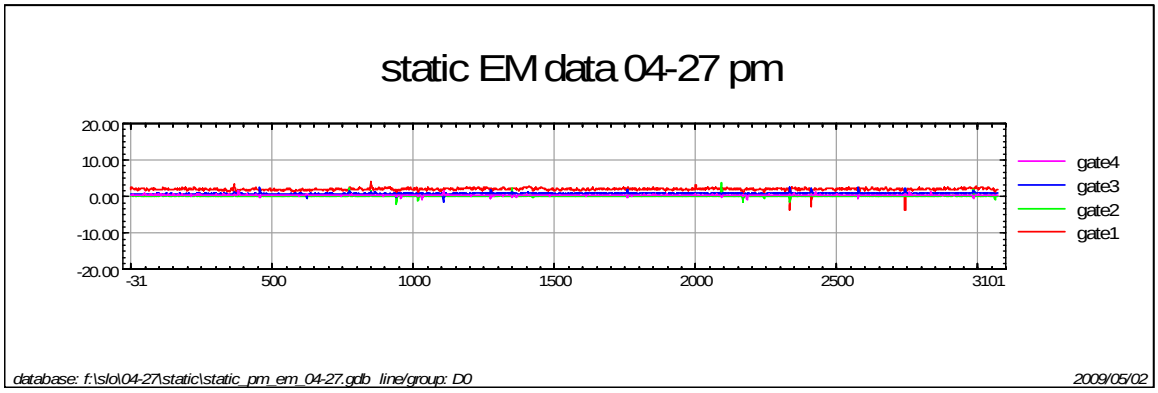
The result of the above was two dig sheets – a magnetometer dig sheet and an EM61 MkII dig sheet. These two lists were spatially cross-correlated to create a single dig sheet listing, for each target, whether it was detected by the magnetometer, the EM61, or both.

Plots of Static Data

Three minutes of static data was acquired at the beginning of the calibration strip at the start and end of every day on each of the 13 survey days, yielding a total of 26 static data tests (each for mag and EM61). All EM61 static data is shown to a vertical scale of -20 to 20mV. It is apparent from looking at the EM61 data that, in some of the plots, there is a source of spurious noise. This is almost certainly from a nearby electric fence; see discussion in the next section. All magnetometer static data is shown to a vertical scale of 40 nT. All magnetometer data plots show data that have been smoothed with a five-point

window to remove the effects of the quantization from storing the data as integers.





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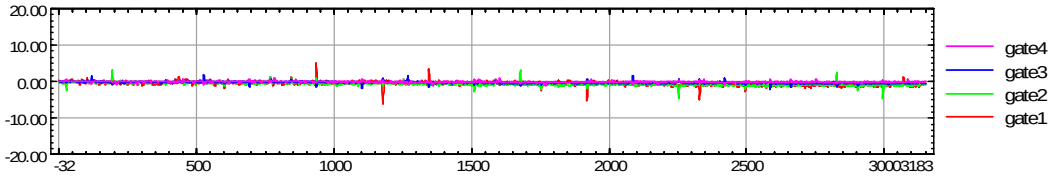

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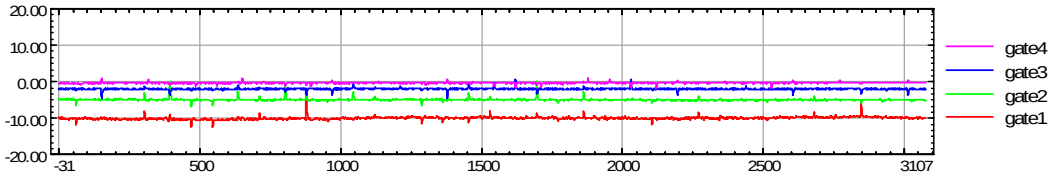

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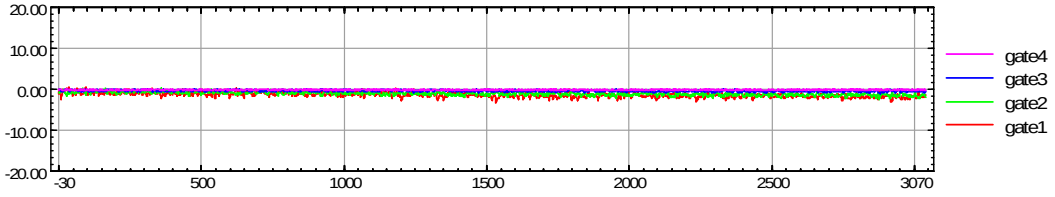

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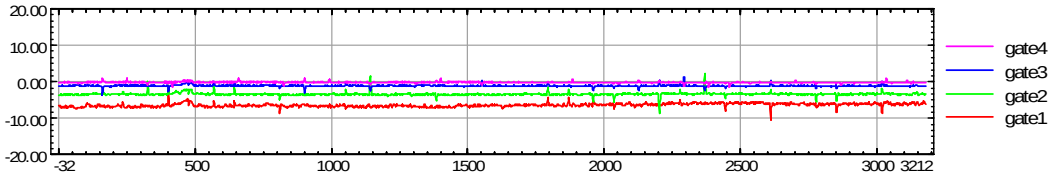

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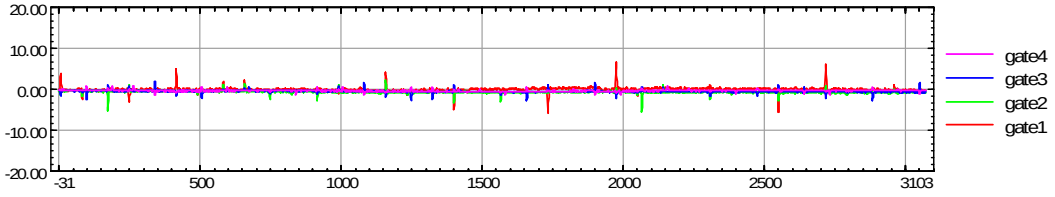

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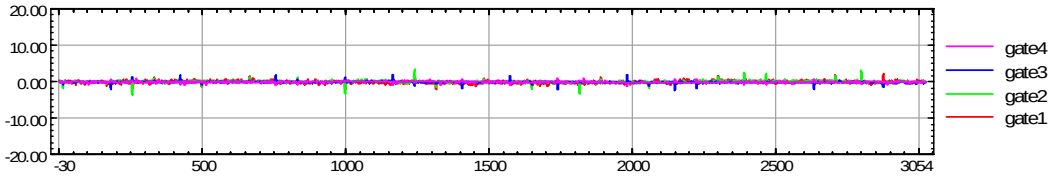

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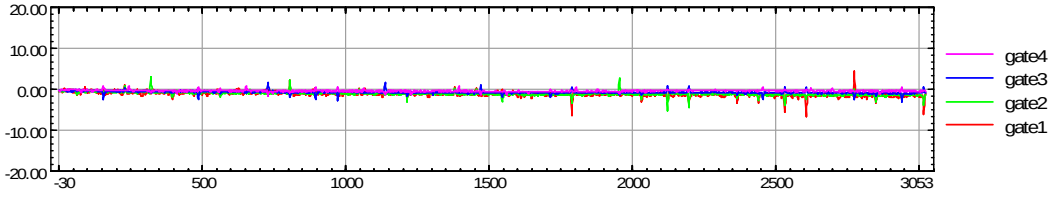

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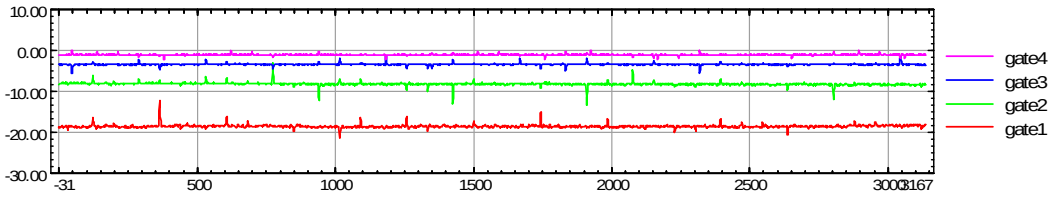

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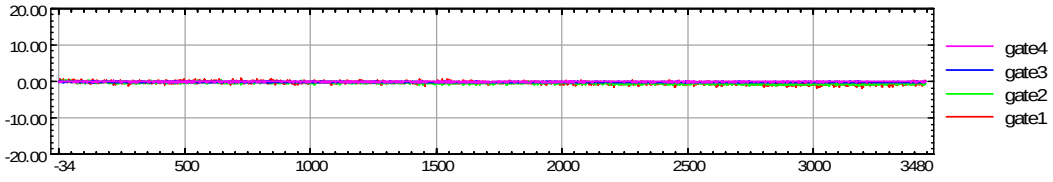

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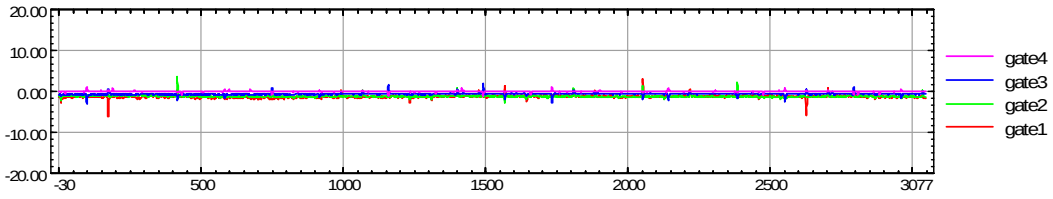

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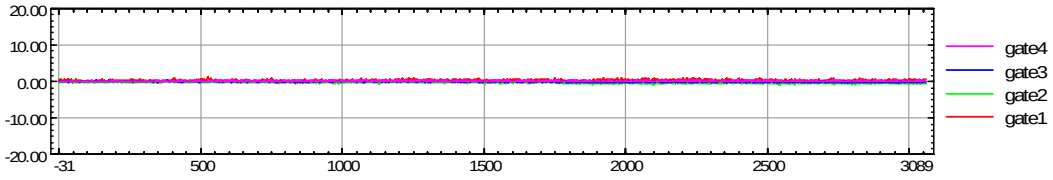

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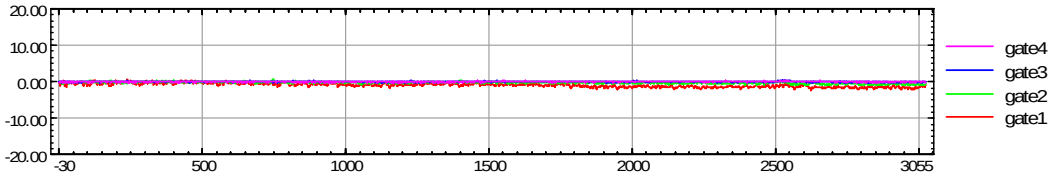

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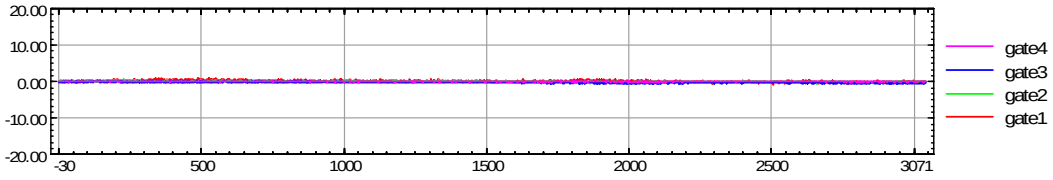

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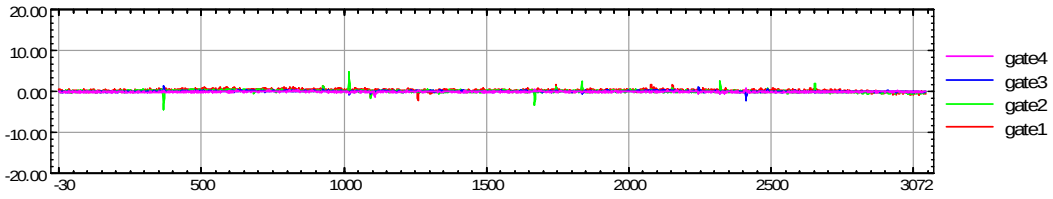

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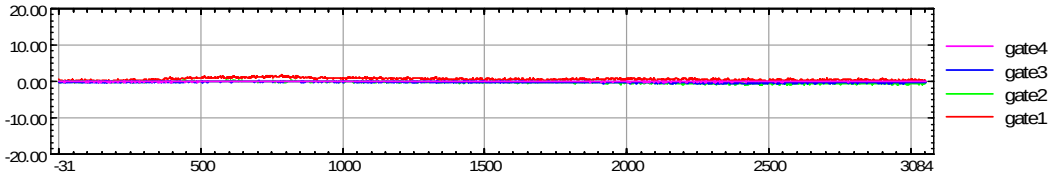

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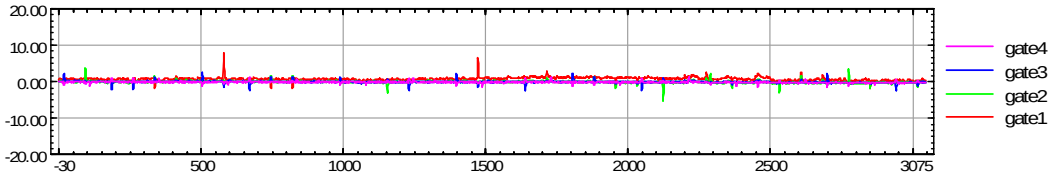

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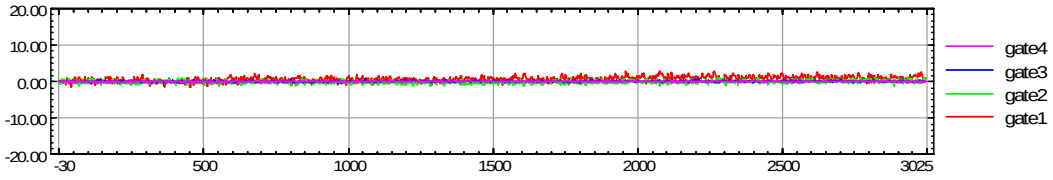

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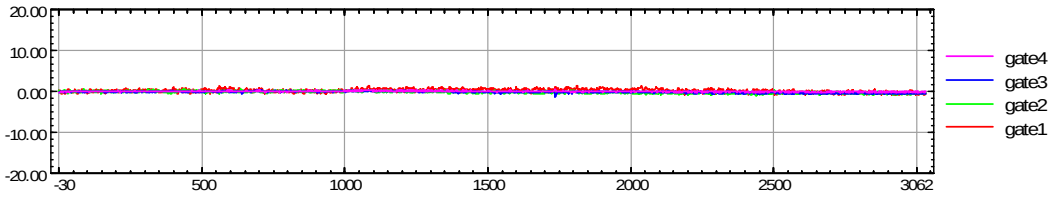

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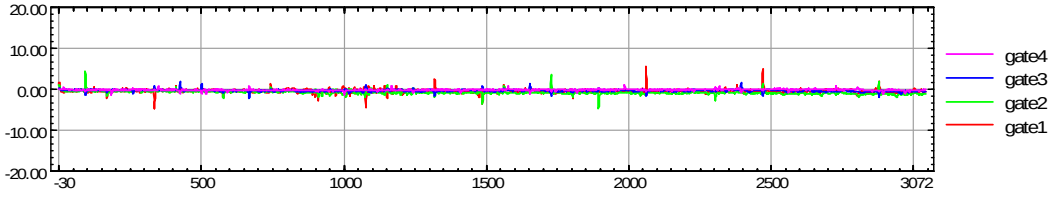

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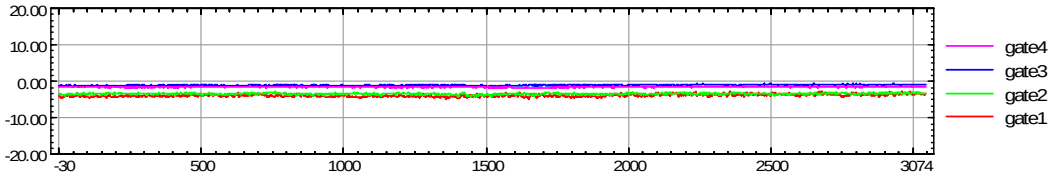

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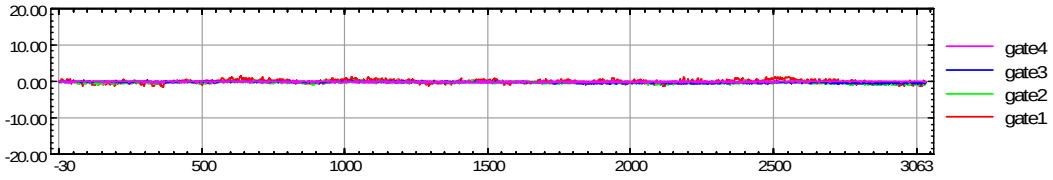

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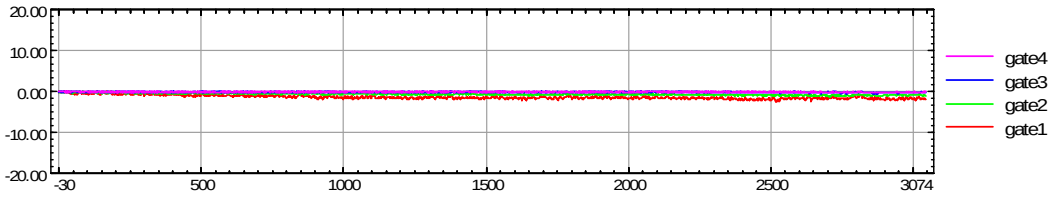

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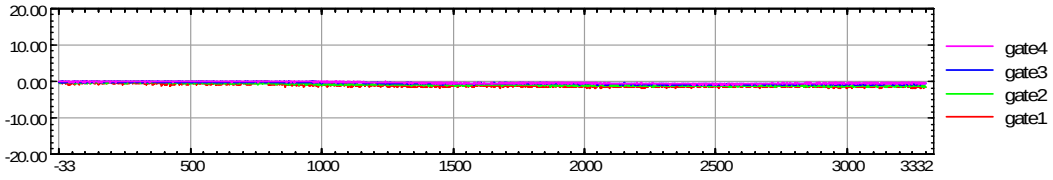

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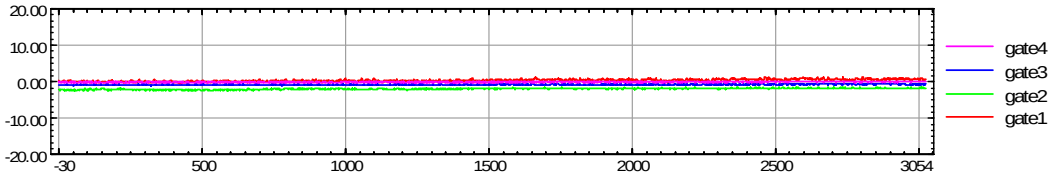

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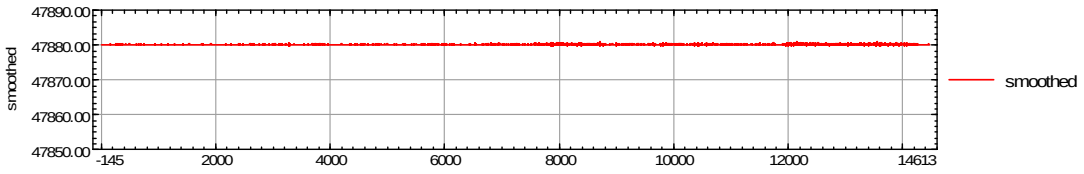

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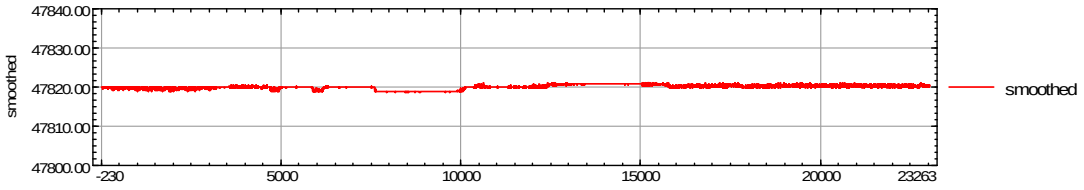
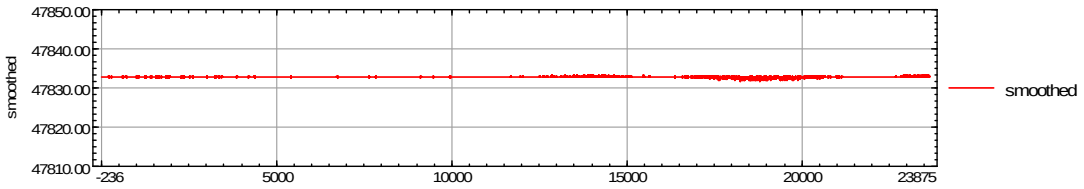
static mag data 04-27 pm



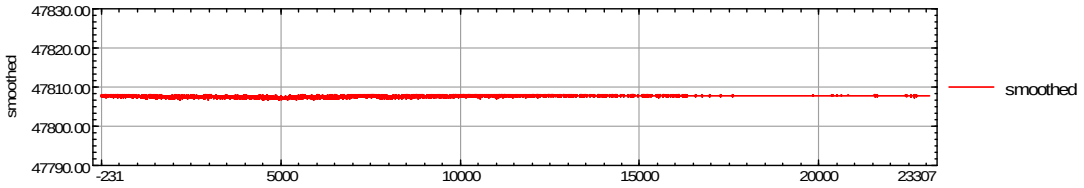
database: f:\slo\04-27\static\static_pm_mag_04-27.gdb line/group: D0 *2009/05/04*

static mag data 04-28 am



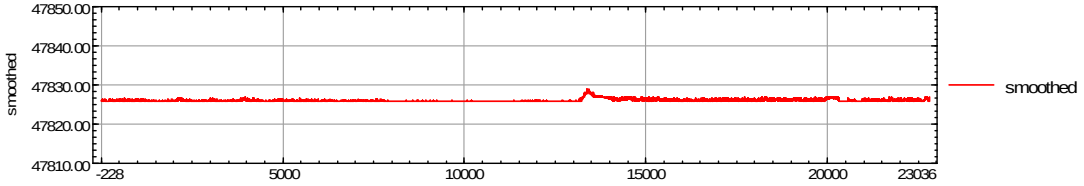
database: f:\slo\04-28\static\static_am_mag_04-28.gdb line/group: D0 *2009/05/04*

static mag data 04-28 pm



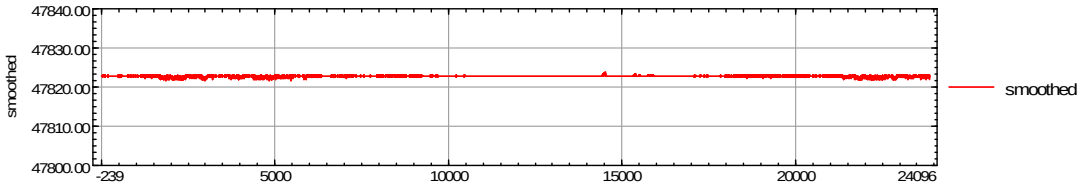
database: f:\slo\04-28\static\static_pm_mag_04-28.gdb line/group: D0 *2009/05/04*

static mag data 04-29 am



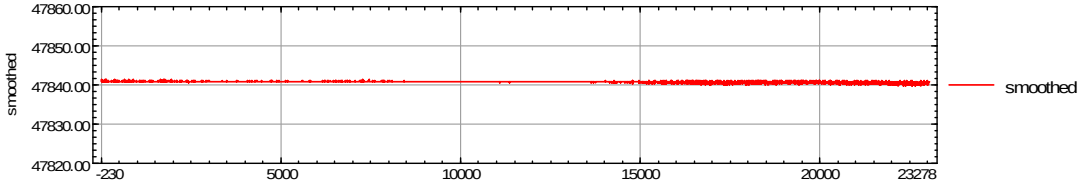
database: f:\slo\04-29\static\static_am_mag_04-29.gdb line/group: D0 *2009/05/04*

static mag data 04-29 pm



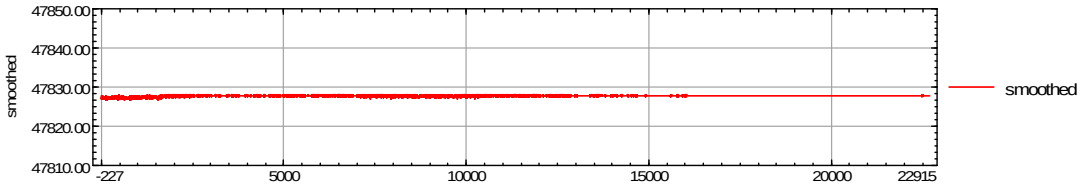
database: f:\slo\04-29\static\static_pm_mag_04-29.gdb line/group: D0 *2009/05/04*

static mag data 04-30 am



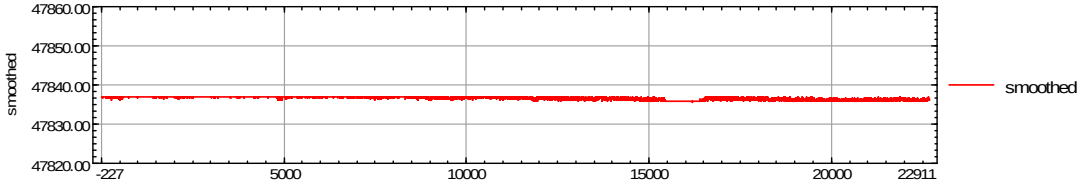
database: f:\slo\04-30\static\static_am_mag_04-30.gdb line/group: D0 *2009/05/04*

static mag data 04-30 pm



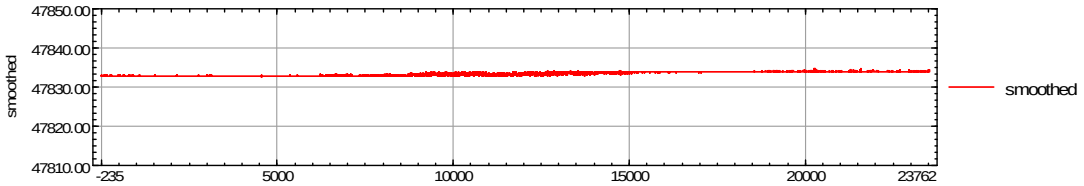
database: f:\slo\04-30\static\static_pm_mag_04-30.gdb line/group: D0 *2009/05/04*

static mag data 05-01 am



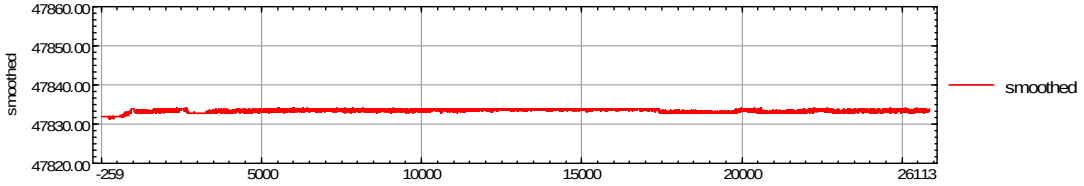
database: f:\slo\05-01\static\static_am_mag_05-01.gdb line/group: D0 *2009/05/04*

static mag data 05-01 pm



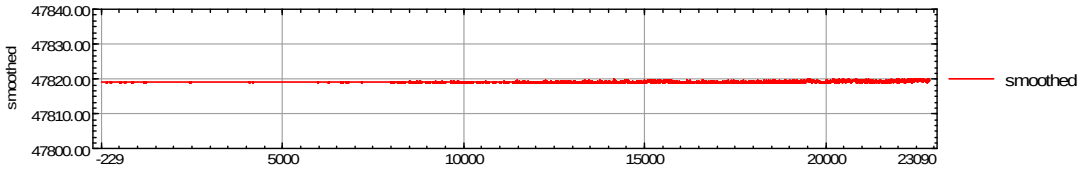
database: f:\slo\05-01\static_pm_mag_05-01.gdb line/group: D0 *2009/05/04*

static mag data 05-04 am



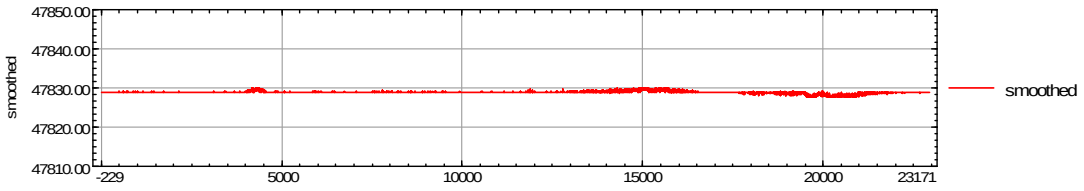
database: f:\slo\05-04\static\static_am_mag_05-04.gdb line/group: D0 *2009/05/04*

static mag data 05-04 pm



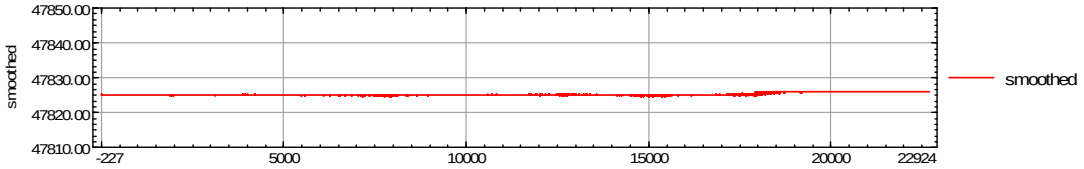
database: f:\slo\05-04\static\static_pm_mag_05-04.gdb line/group: D0 *2009/05/05*

static mag data 05-05 am



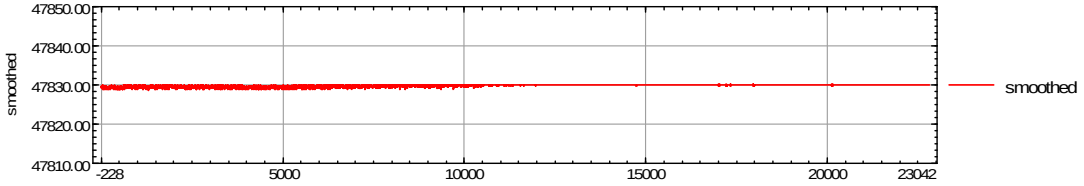
database: f:\slo\05-05\static\static_am_mag_05-05.gdb line/group: D0 *2009/05/05*

static mag data 05-05 pm



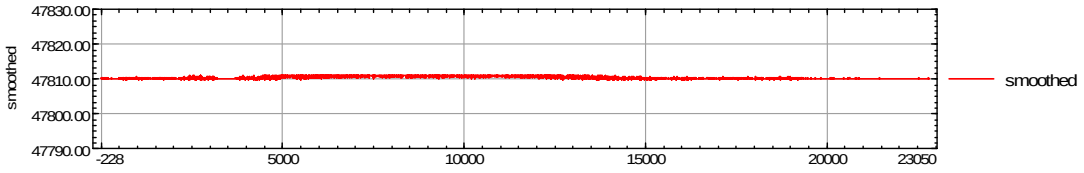
database: f:\slo\05-05\static\static_pm_mag_05-05.gdb line/group: D0 *2009/05/06*

static mag data 05-06 am



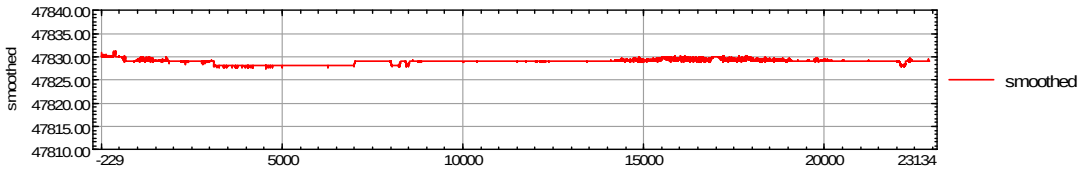
database: f:\slo\05-06\static\static_am_mag_05-06.gdb line/group: D0 *2009/05/06*

static mag data 05-06 pm



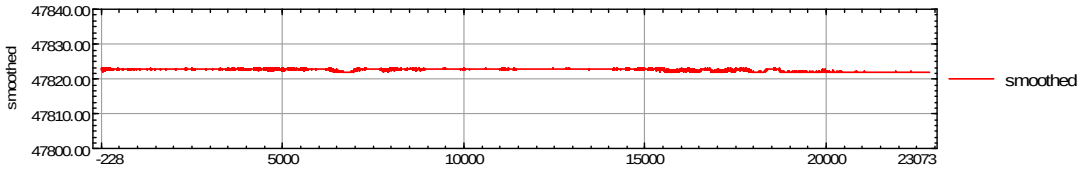
database: f:\slo\05-06\static\static_pm_mag_05-06.gdb line/group: D0 *2009/05/07*

static mag data 05-07 am



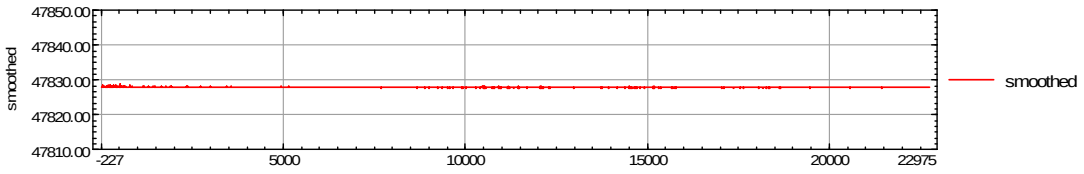
database: f:\slo\05-07\static\static_am_mag_05-07.gdb line/group: D0 *2009/05/07*

static mag data 05-07 pm



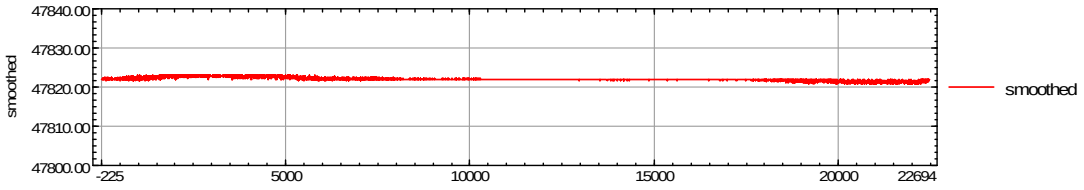
database: f:\slo\05-07\static\static_pm_mag_05-07.gdb line/group: D0 *2009/05/08*

static mag data 05-08 am



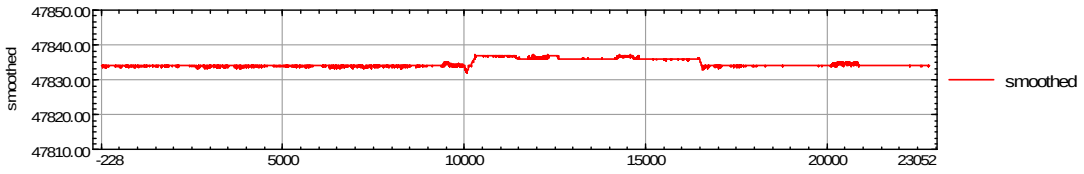
database: f:\slo\05-08\static\static_am_mag_05-08.gdb line/group: D0 *2009/05/08*

static mag data 05-08 pm



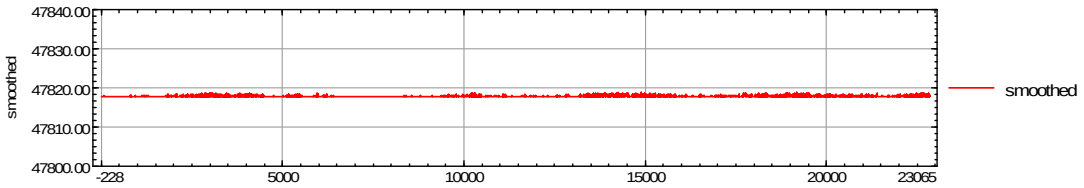
database: f:\slo\05-08\static\static_pm_mag_05-08.gdb line/group: D0 *2009/05/10*

static mag data 05-11 am



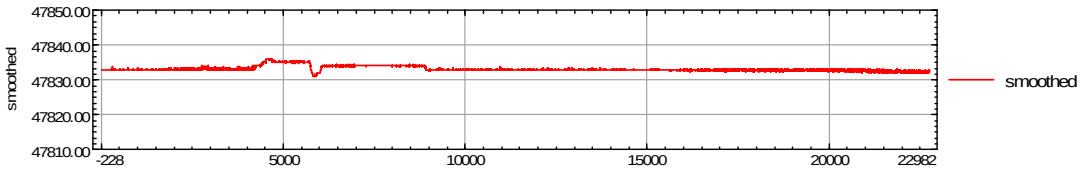
database: f:\slo\05-11\static\static_am_mag_05-11.gdb line/group: D0 *2009/05/11*

static mag data 05-11 pm



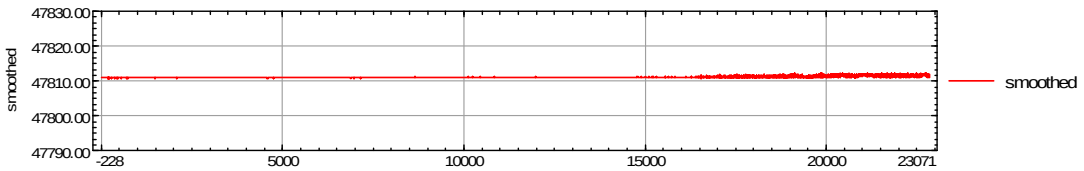
database: f:\slo\05-11\static\static_pm_mag_05-11.gdb line/group: D0 *2009/05/11*

static mag data 05-12 am

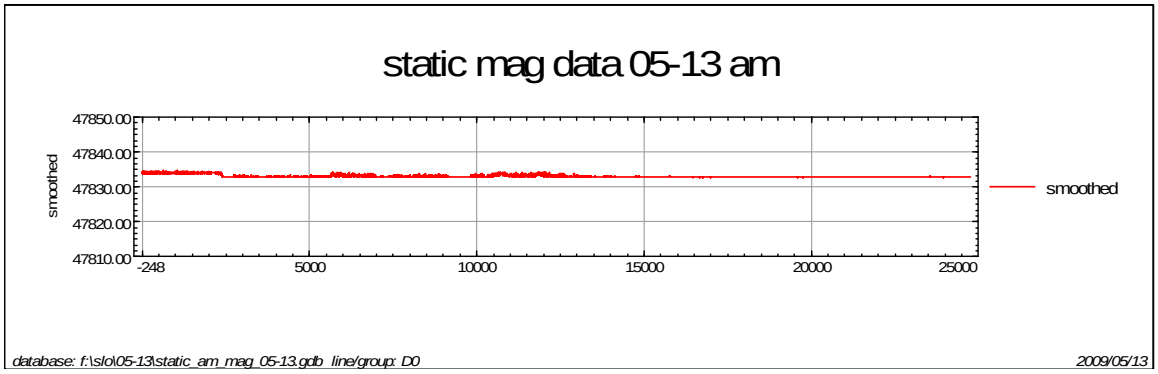


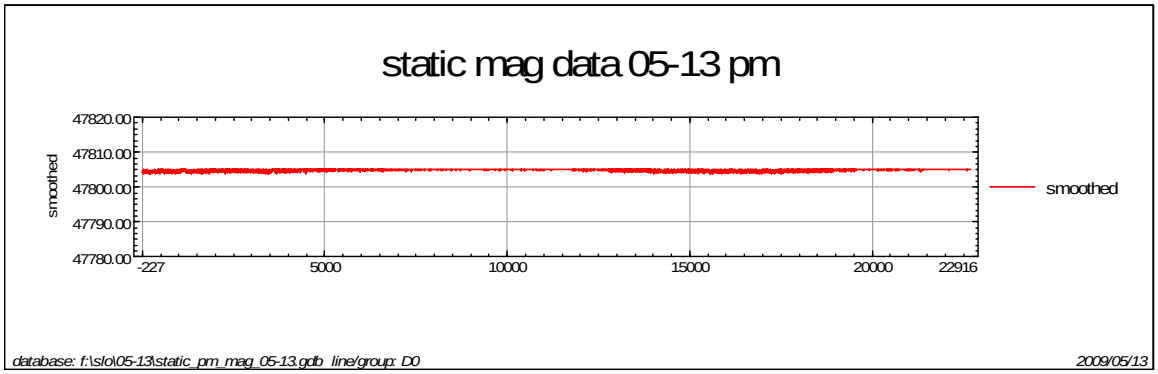
database: f:\slo\05-12\static\static_am_mag_05-12.gdb line/group: D0 *2009/05/12*

static mag data 05-12 pm



database: f:\slo\05-12\static\static_pm_mag_05-12.gdb line/group: D0 *2009/05/13*





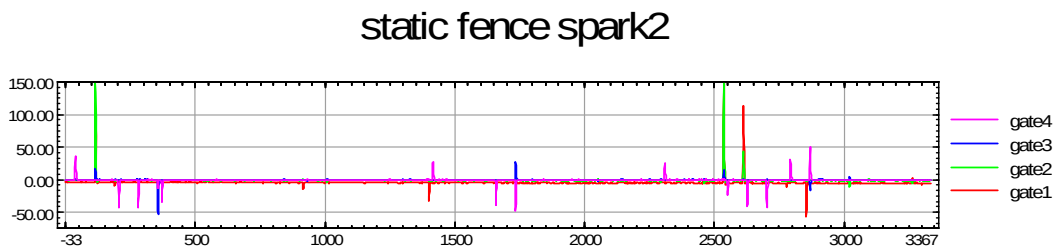
Noise

Magnetometer Data: There is no apparent source of ambient noise in the static magnetometer data; most of the static magnetometer plots visually appear flat, and when analyzed in Oasis, have a standard deviation of about 0.2 nT. Even in those (such as 5-12 am) where it appears that an operator may have walked close to the magnetometer still have a standard deviation less than 1nT. There is no significant magnetic geology in the test strip, but there are substantial magnetic gradients – hundreds of nanotesla – in the survey area. Even the training pit has a magnetic gradient of approximately 150 nT across its short length.

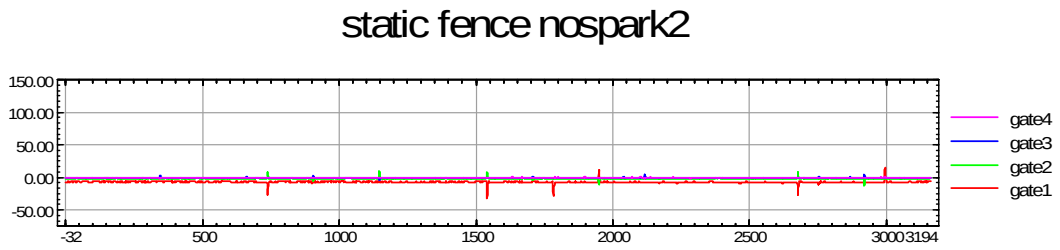
EM61 Data: It is clear from examining the static EM61 data that, in some of the data sets, there is a source of spurious noise. A relatively quiet static plot such as 4/29 AM has a standard deviation of 0.42mV on gate2 with a total range of 2.7mV, whereas a noisy one such as 4/27 AM has a standard deviation of 1.22mV on gate2 with a total range of 30.5mV.

Electric Fence as Cause of Spurious Noise on EM61 Data

As per communication with the Program Office while we were on site, at some point during the survey, the NAEVA crew alerted us that they had seen similar noise in the standalone EM61 data that they'd previously acquired, and offered unsubstantiated a priori knowledge that it was due to the electric fence surrounding the site. One of the crew members noticed that a section of the electric fence was arcing (sparking to ground) due to a portion of an insulated section of cable that had worn through its insulation as it passed through a metal stand-off, causing visible and audible sparking at that location. We conducted a quick controlled test (one set of data acquired while the fence was arcing, and another acquired once we repaired the insulation with electrical tape). The data show that this arcing was producing large spikes in the EM61 data that were not present when we stopped the arcing. This is shown in the figures below. This shows that the large spikes did indeed seem to be produced by the arcing. This is not to say that the absence of arcing did not guarantee completely noise-free EM61 data; noise and smaller spikes were still present in the EM61 data even after we repaired the worn insulation. .



Static EM61 data acquired near arcing fence



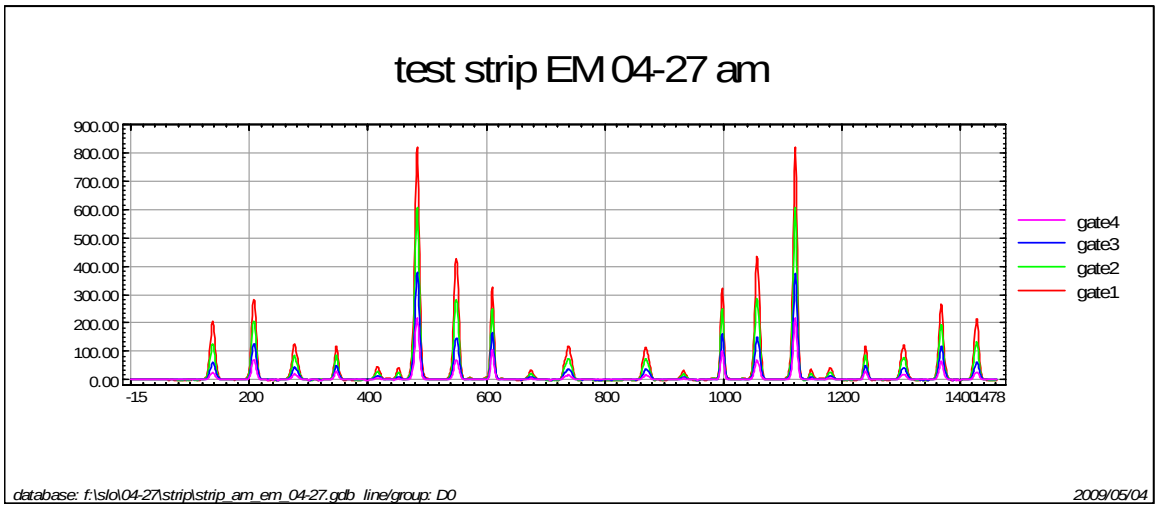
Static EM61 data acquired near fence with arcing repaired

Plots of Calibration Strip Data

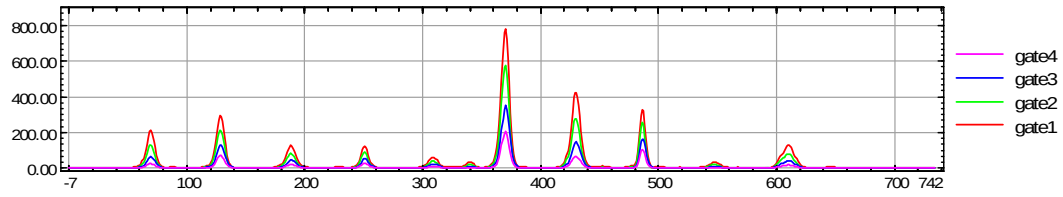
The calibration strip was located in a fairly geologically inert area on the Southern boundary of the survey area and was traversed with MSEMS at the start and end of every day on each of the 13 survey days, yielding a total of 26 calibration strip files (each for mag and EM61). As per section 5.2.7 of the Program Office's SLO Demonstration Plan, the following items were in the calibration strip:

T-001 shotput 0.45 N/A N/A
T-002 81mm 0.30 Vertical Down 0
T-003 81mm 0.30 Horizontal 120
T-004 60mm 0.30 Vertical Down 0
T-005 60mm 0.30 Horizontal 120
T-006 4.2" mortar 0.30 Vertical Down 0
T-007 4.2" mortar 0.30 Horizontal 120
T-008 2.36" rocket 0.30 Vertical Down 0
T-009 2.36" rocket 0.30 Horizontal 120
T-010 shotput 0.45 N/A N/A

On the first run of the first day, the calibration strip was surveyed "there and back." On all other runs, a single outgoing pass was collected. Plots of the EM and magnetometer calibration strip data are below. All EM61 plots show leveled EM61 data, all four gates, to a scale of 800 mV (except for the first one which is 900 mV), and the ordinate is the 10Hz sample number. All magnetometer calibration strip plots are displayed to a vertical scale of 300nT, and the ordinate is the 75Hz sample number.

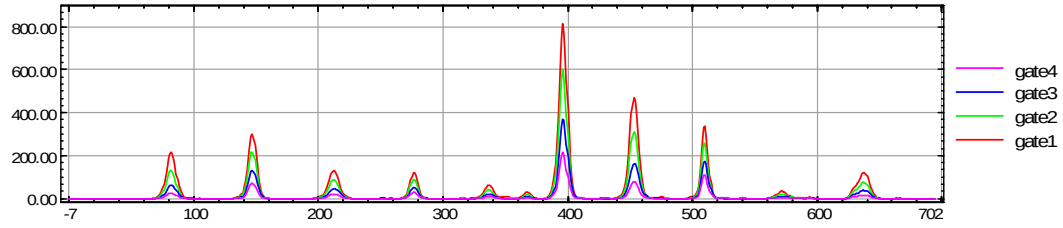


test strip EM 04-27 pm



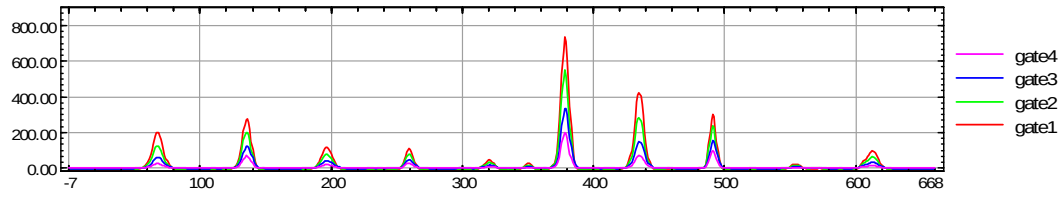
database: f:\slo\04-27\strip\strip_pm_em_04-27.gdb line/group: D0 *2009/05/04*

test strip EM 04-28 am



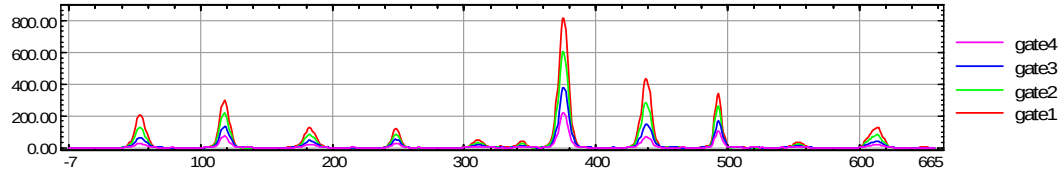
database: f:\slo\04-28\strip\strip_am_em_04-28.gdb line/group: D0 *2009/05/04*

test strip EM 04-28 pm



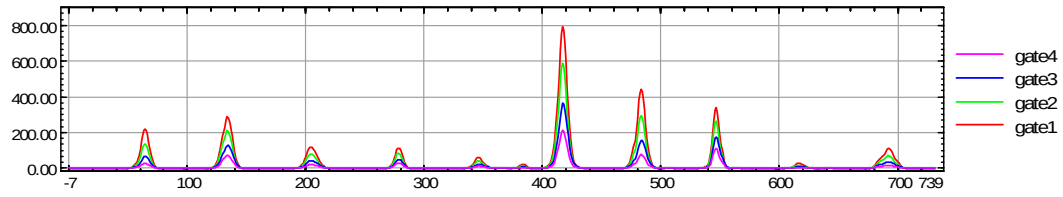
database: f:\slo\04-28\strip\strip_pm_em_04-28.gdb line/group: D0 *2009/05/04*

test strip EM 04-29 am



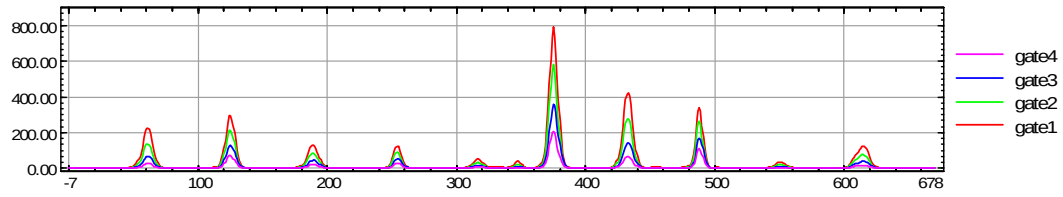
database: f:\slo\04-29\strip\strip_am_em_04-29.gdb line/group: D0 *2009/05/04*

test strip EM 04-29 pm



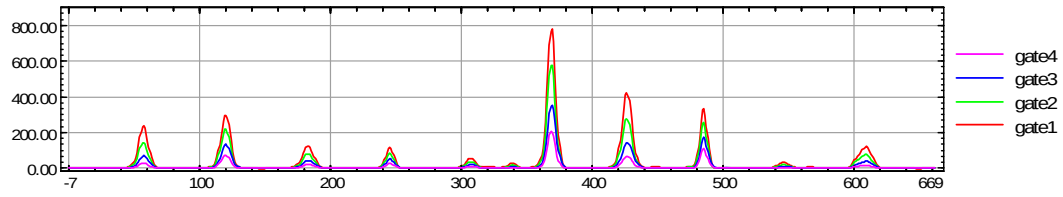
database: f:\slo\04-29\strip\strip_pm_em_04-29.gdb line/group: D0 *2009/05/04*

test strip EM 04-30 am



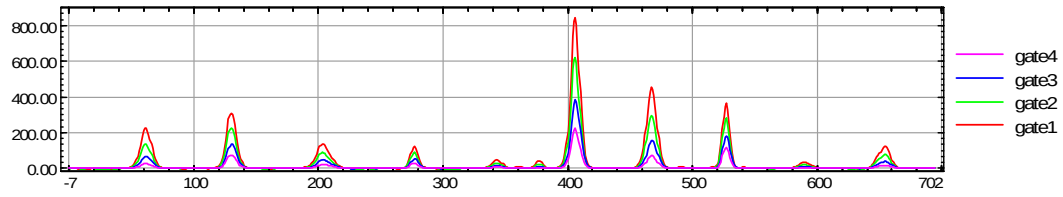
database: f:\slo\04-30\strip\strip_am_em_04-30.gdb line/group: D0 *2009/05/04*

test strip EM 04-30 pm



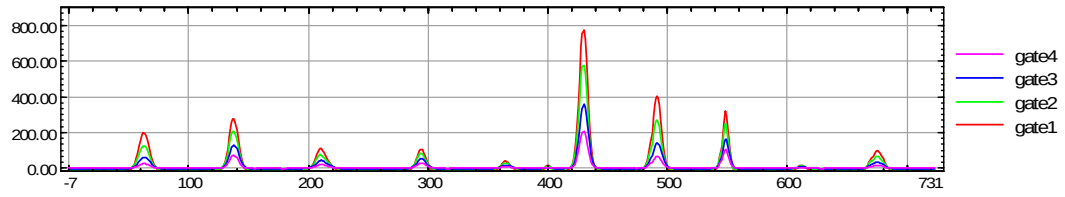
database: f:\slo\04-30\strip\strip_pm_em_04-30.gdb line/group: D0 *2009/05/04*

test strip EM 05-01 am



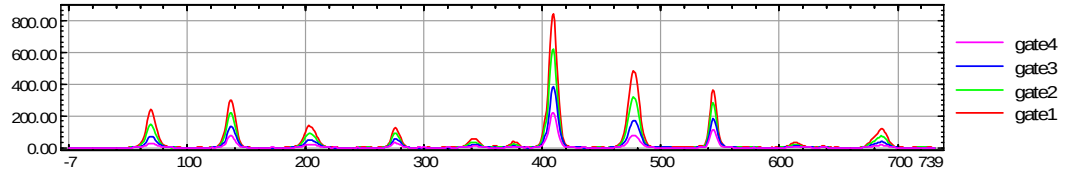
database: f:\slo\05-01\strip\strip_am_em_05-01.gdb line/group: D0 *2009/05/04*

test strip EM 05-01 pm



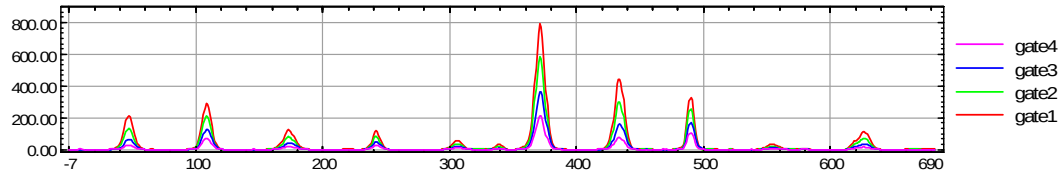
database: f:\slo\05-01\strip\strip_pm_em_05-01.gdb line/group: D0 *2009/05/04*

test strip EM 05-04 am



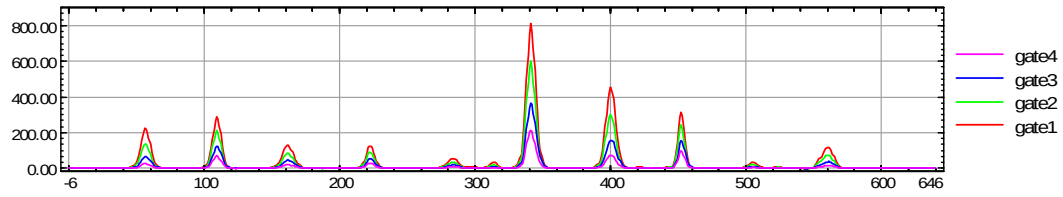
database: f:\slo\05-04\strip\strip_am_em_05-04.gdb line/group: D0 *2009/05/04*

test strip EM 05-04 pm



database: f:\slo\05-04\strip\strip_pm_em_05-04.gdb line/group: D0 *2009/05/05*

test strip EM 05-05 am



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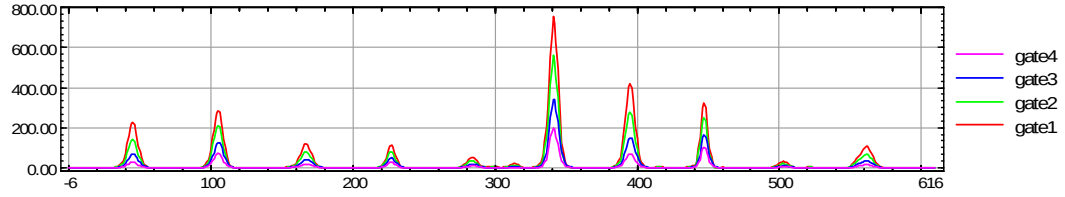
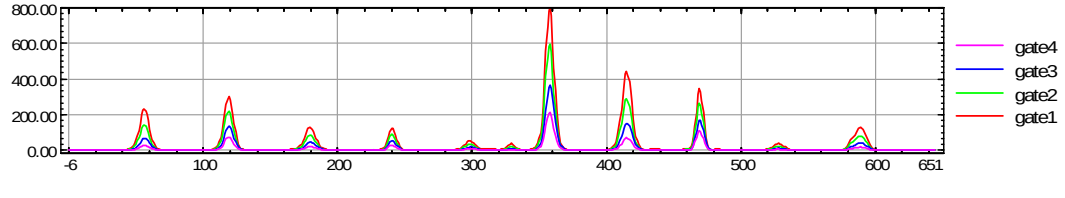
test strip EM 05-05 pm



database: f:\slo\05-05\strip\strip_pm_em_05-05.gdb line/group: D0 *2009/05/06*

test strip EM 05-06 am



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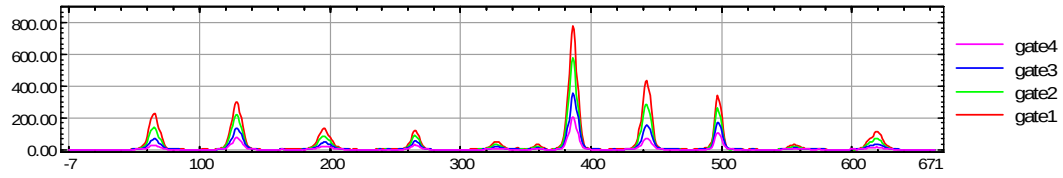
test strip EM 05-06 pm



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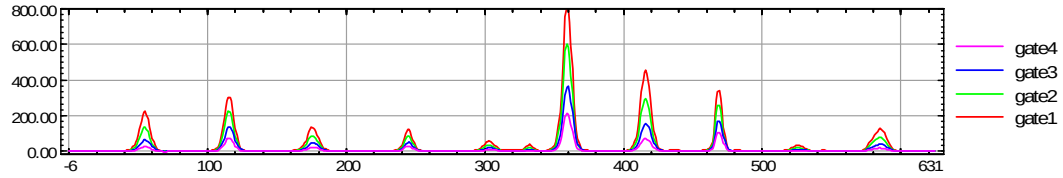
test strip EM 05-07 pm



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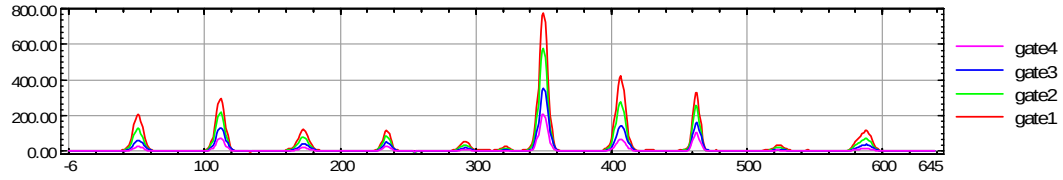

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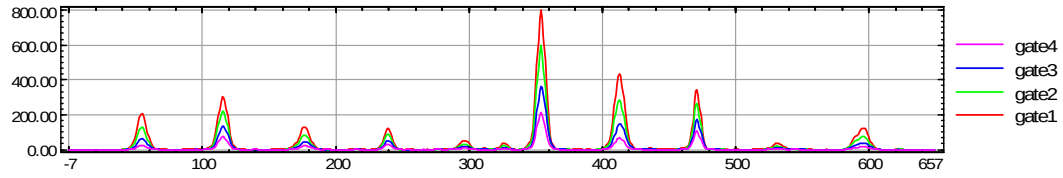
test strip EM 05-08 am



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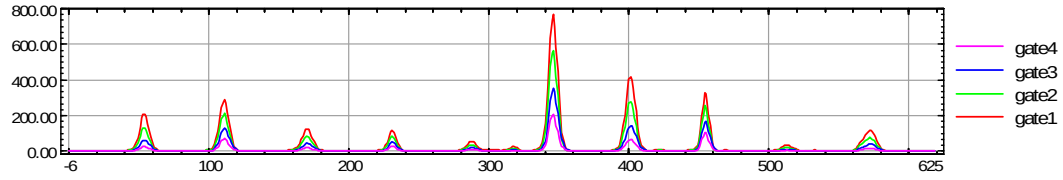

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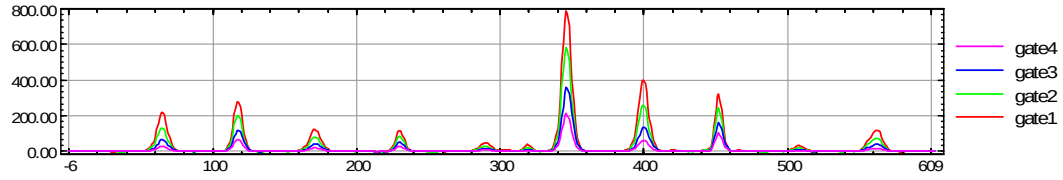
test strip EM 05-11 am



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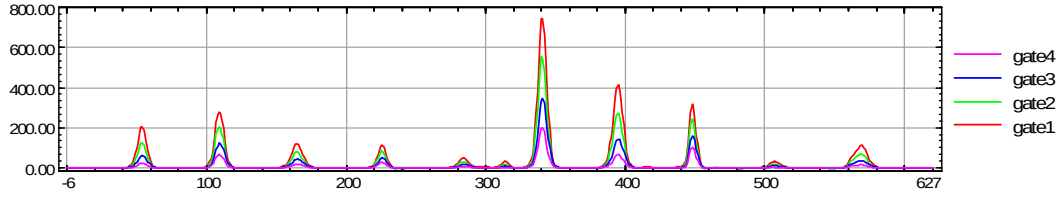
test strip EM 05-11 pm



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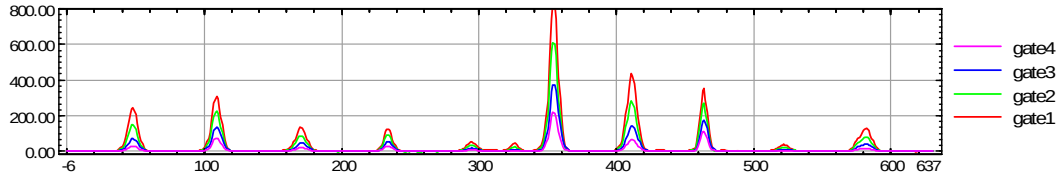
test strip EM 05-12 am



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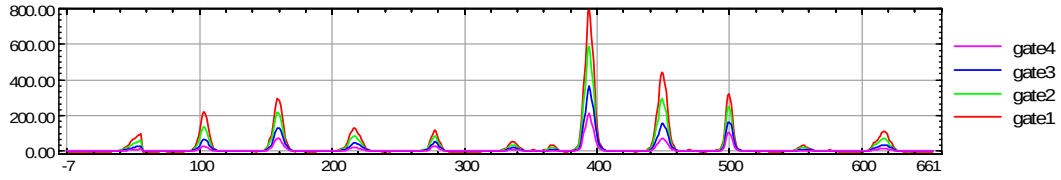

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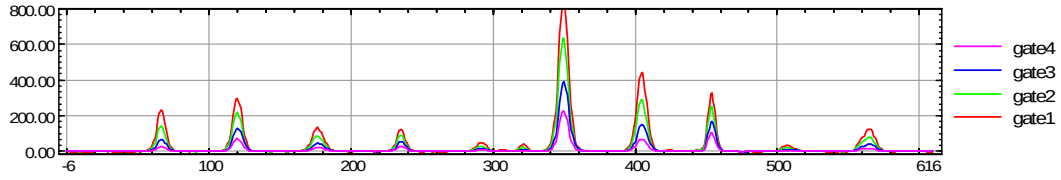
test strip EM 05-13 am



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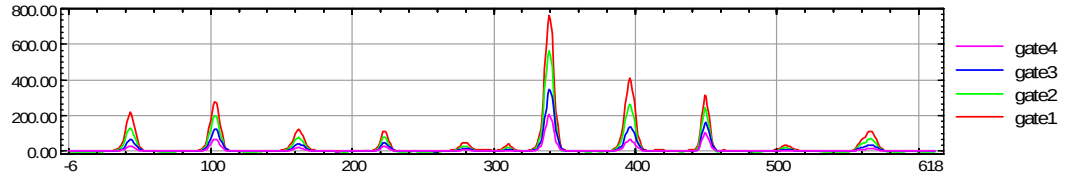

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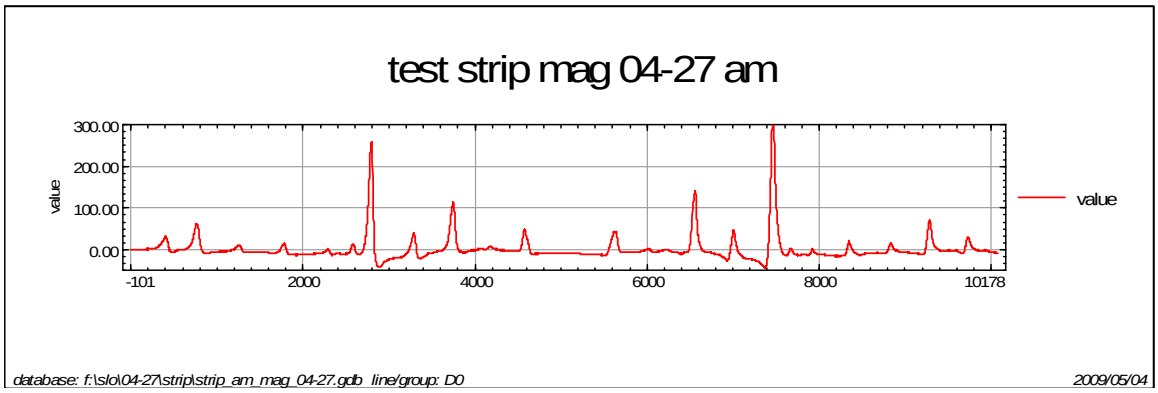
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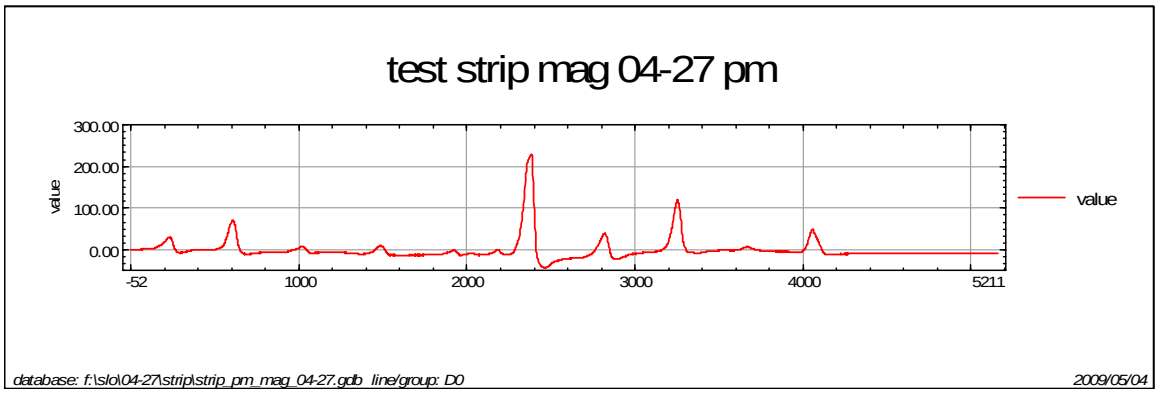
200.00
100.00
0.00
value
-101
2000
4000
6000
8000
10178
value
database: f:\slo\04-27\strip\strip_am_mag_04-27.gdb line/group: D0
2009/05/04


test strip mag 04-27 pm
300.00
200.00
100.00
0.00
value
-52
1000
2000
3000
4000
5211
value
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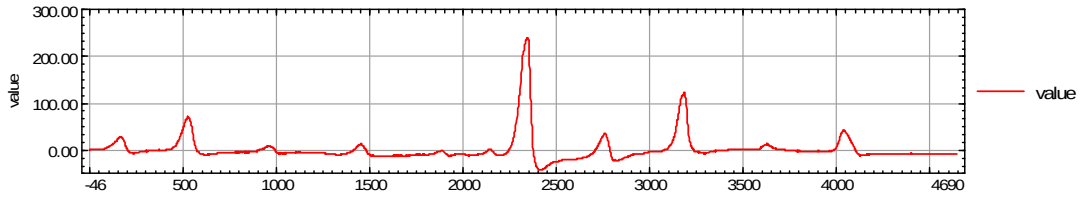
2009/05/04

test strip mag 04-28 am



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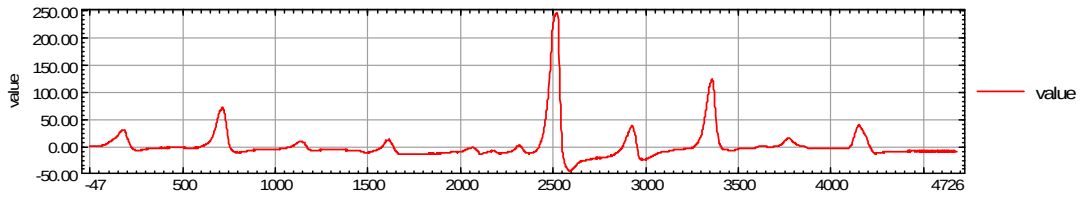

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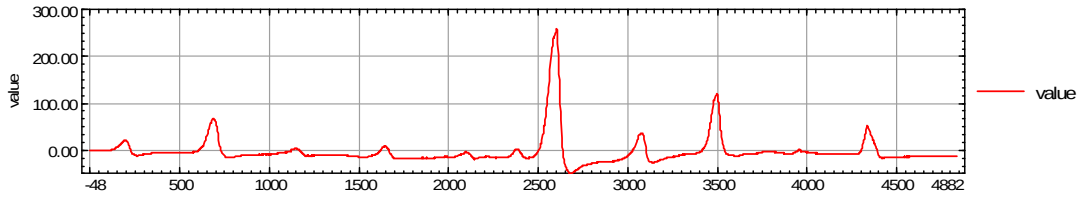
test strip mag 04-29 am



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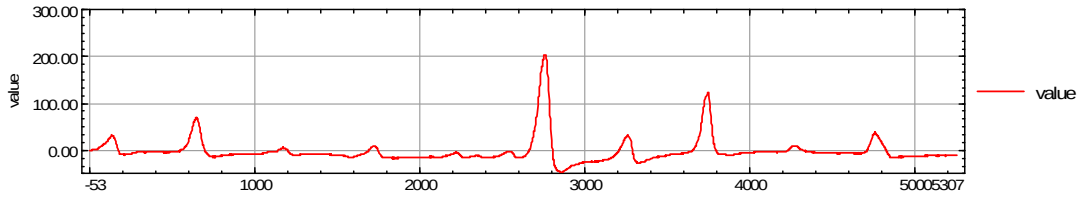

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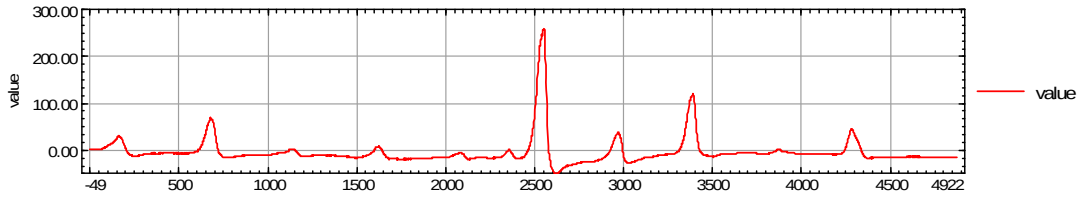
test strip mag 04-30 am



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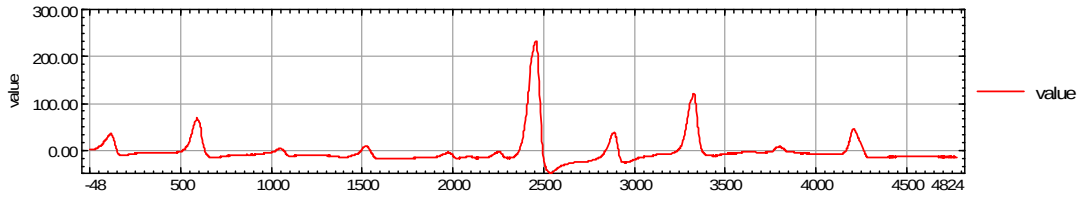

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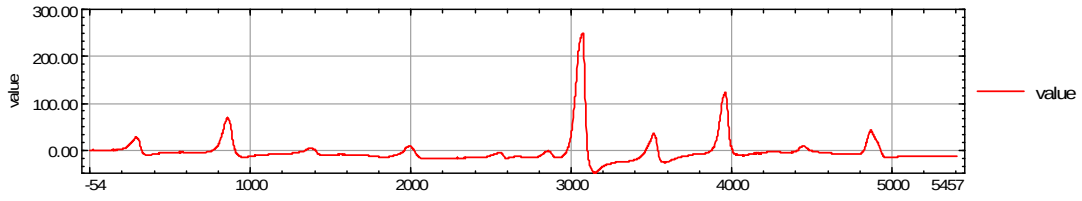

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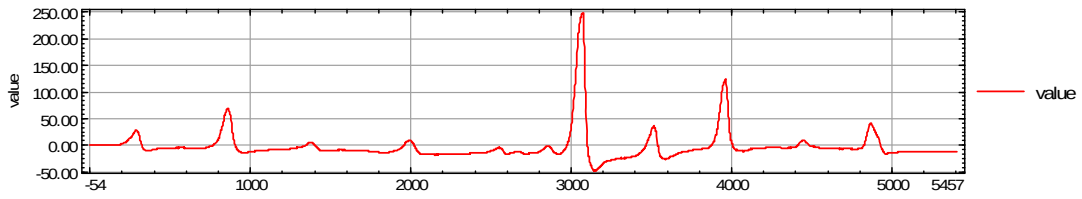
test strip mag 05-01 pm



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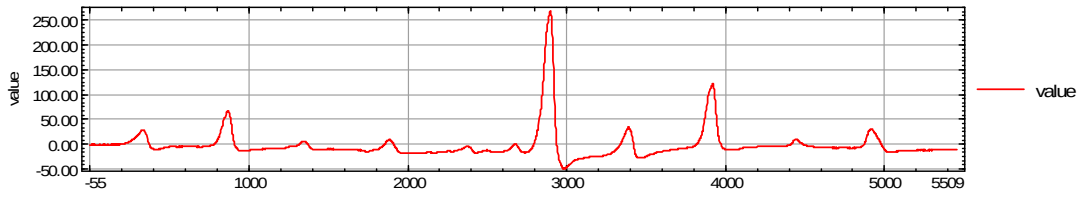

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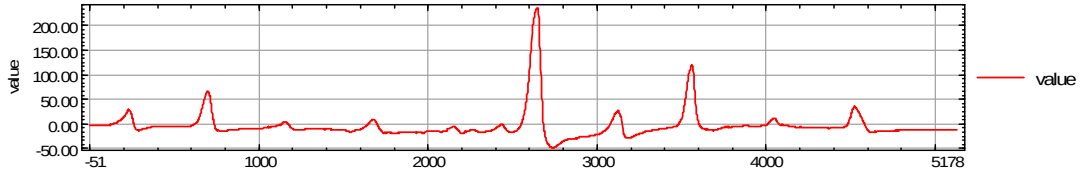
test strip EM 05-04 pm



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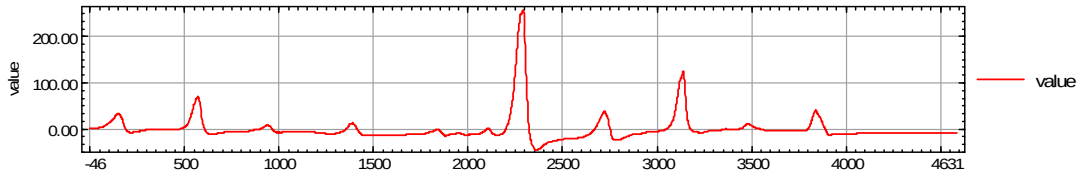

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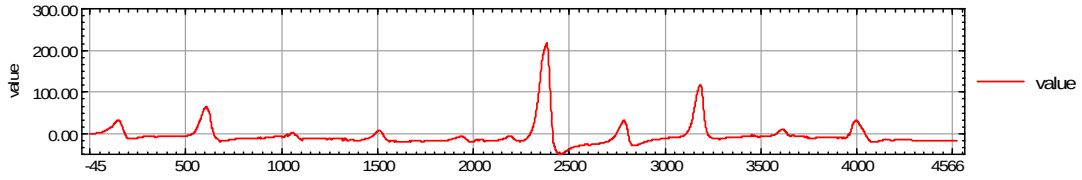
test strip mag 05-05 pm



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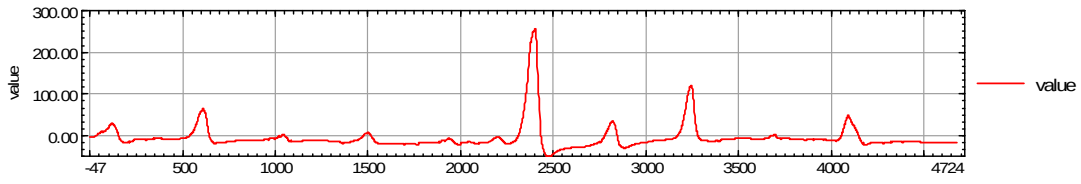
test strip mag 05-06 am



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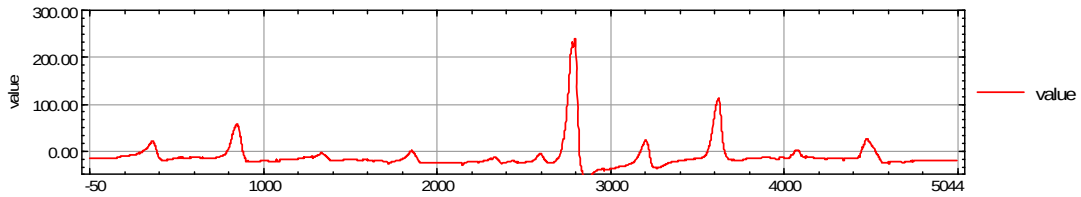
test strip mag 05-06 pm



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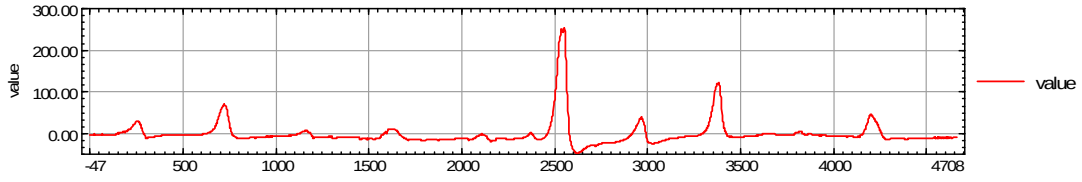

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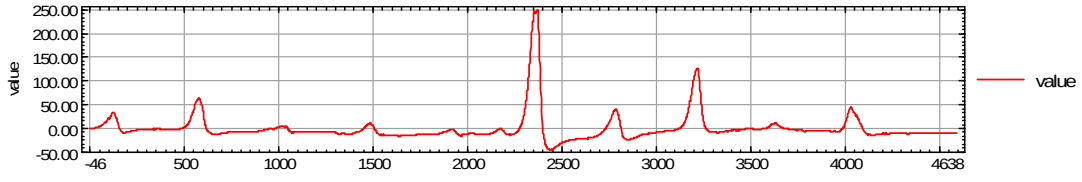

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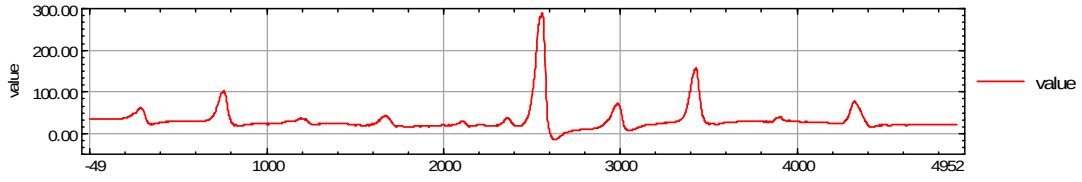

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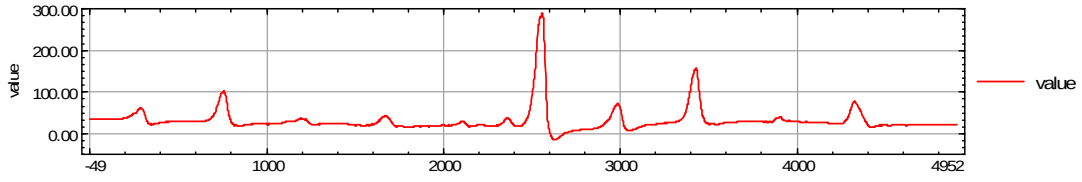
test strip mag 05-08 pm



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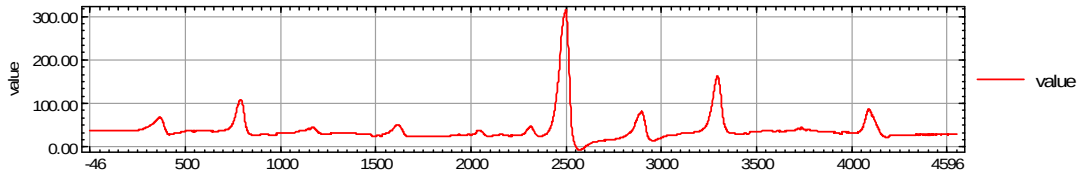

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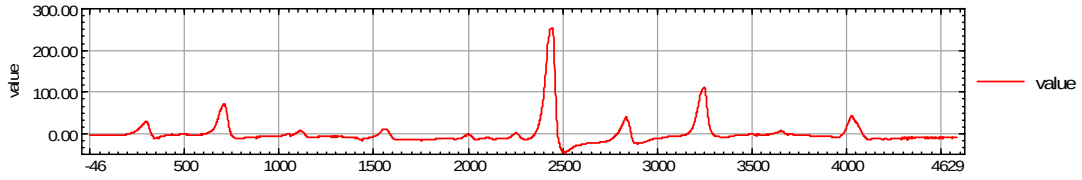
test strip mag 05-11 pm



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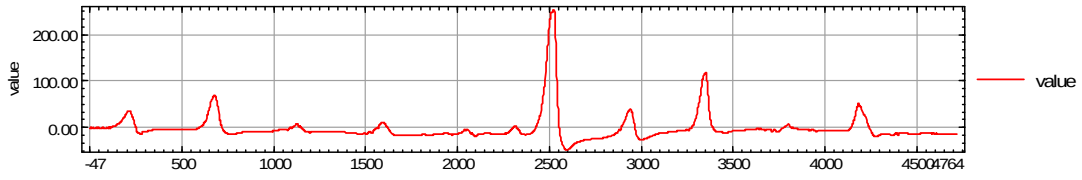

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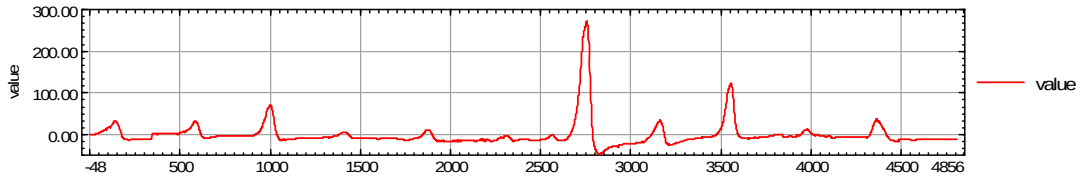
test strip mag 05-12 pm



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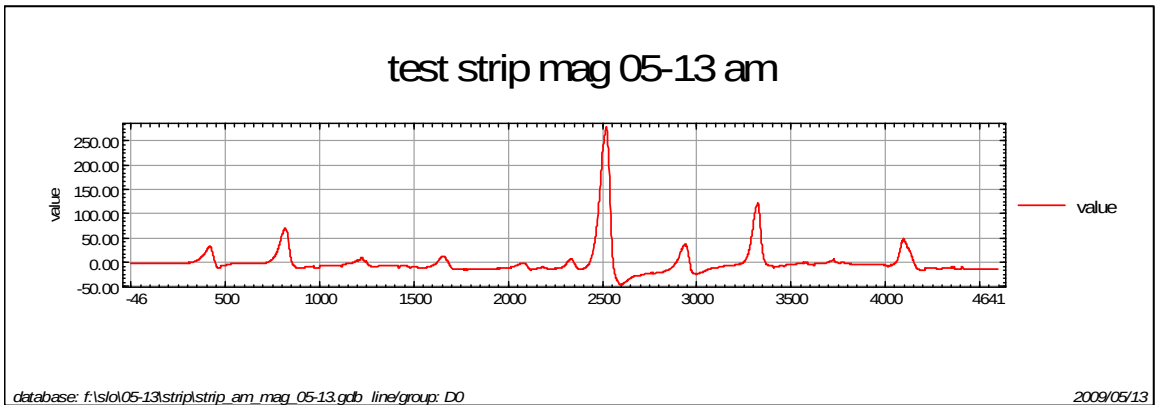
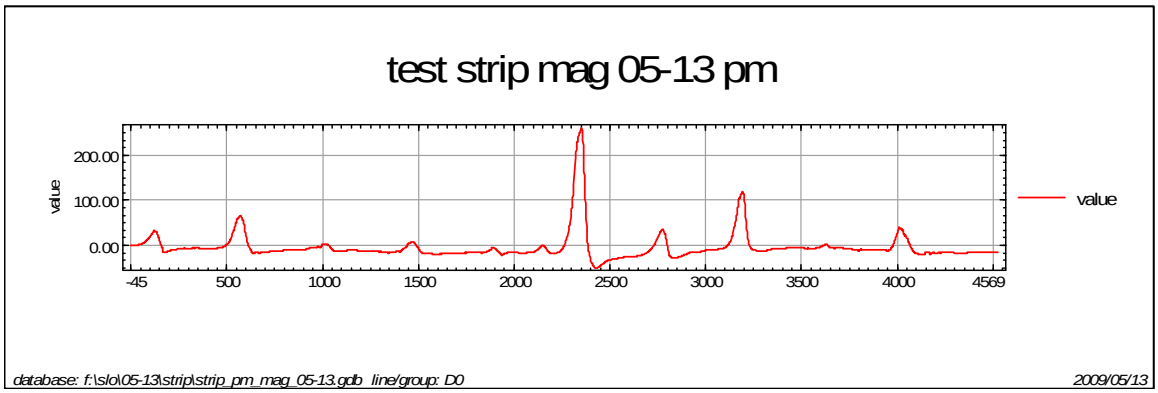




Plots of Item-By-Item Calibration Strip Response Consistency

The graphs below show the calibration strip response results for the magnetometer data.

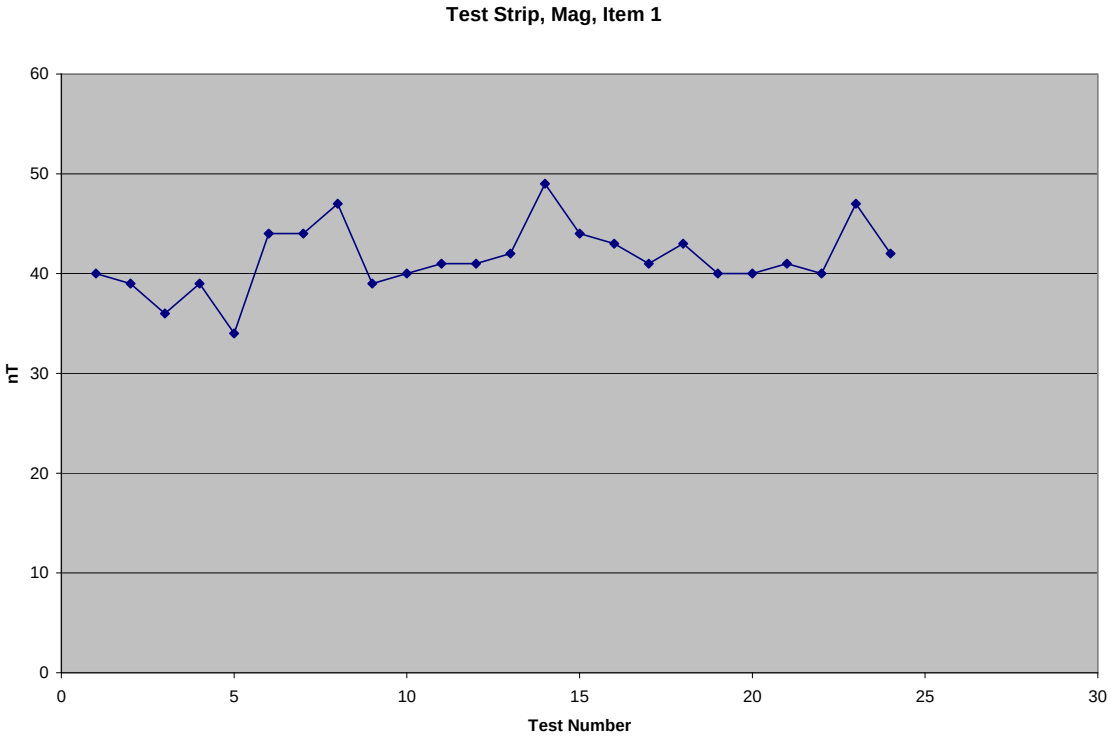


Figure 2: Calibration Strip Magnetometer Response for Item T-001 (Shotput)

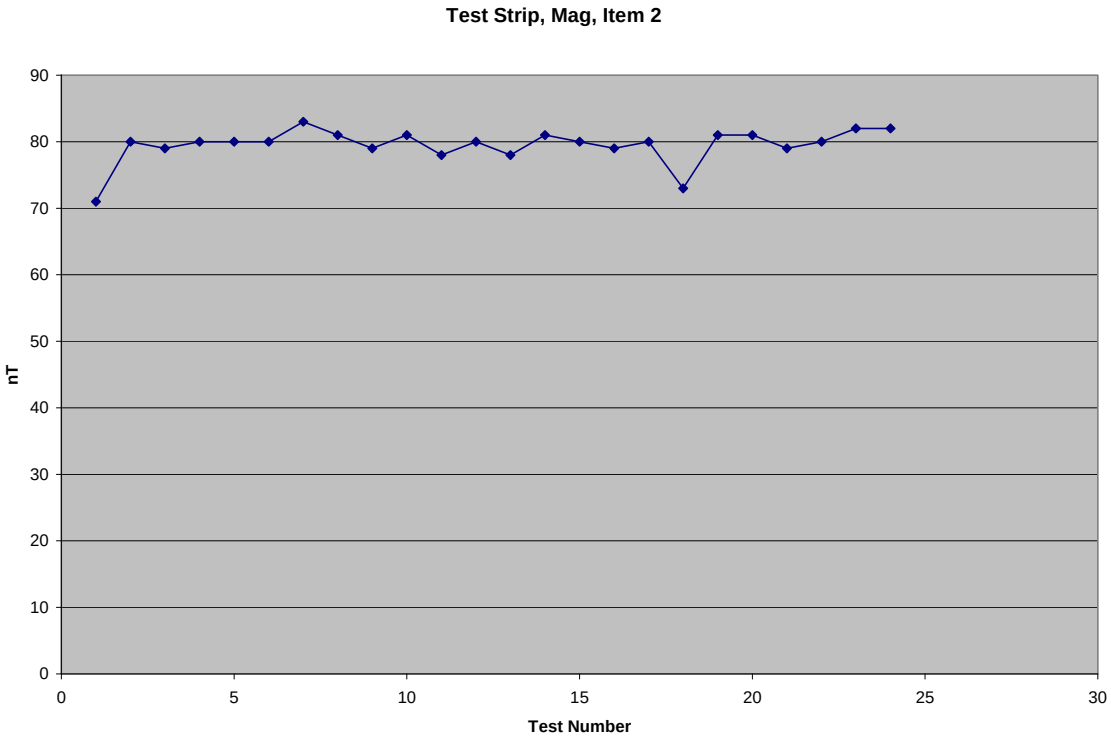


Figure 3: Calibration Strip Magnetometer Response for Item T-002 (81mm vert)

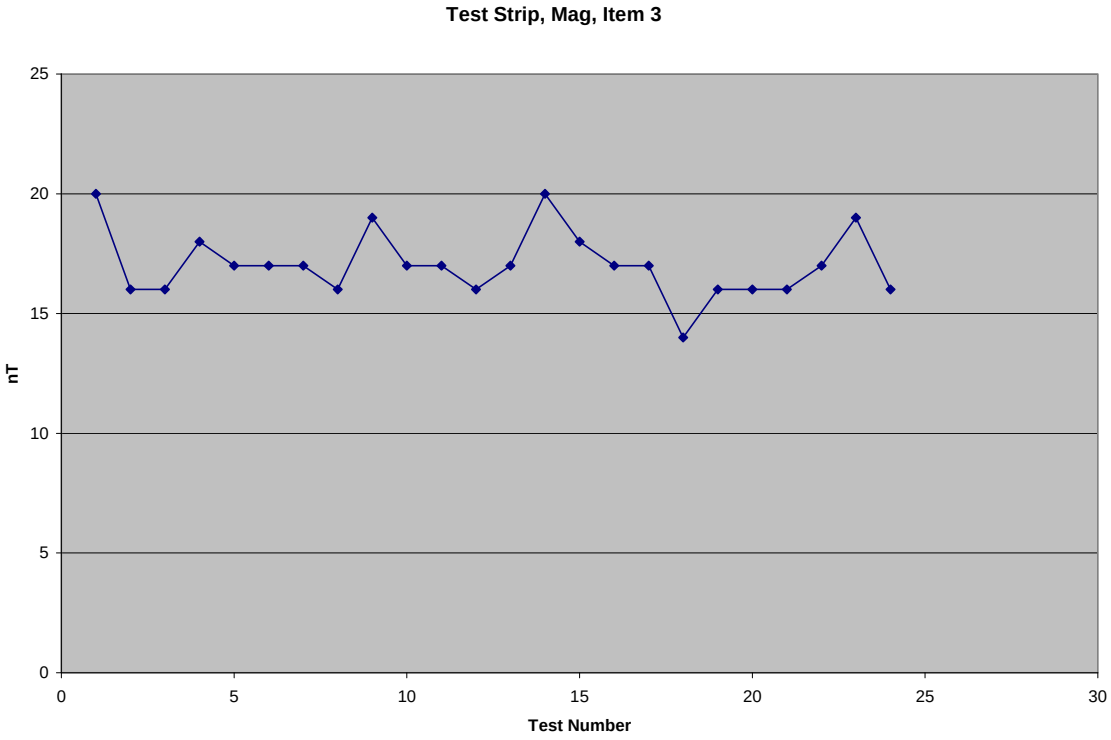


Figure 4: Calibration Strip Magnetometer Response for Item T-002 (81mm horiz)

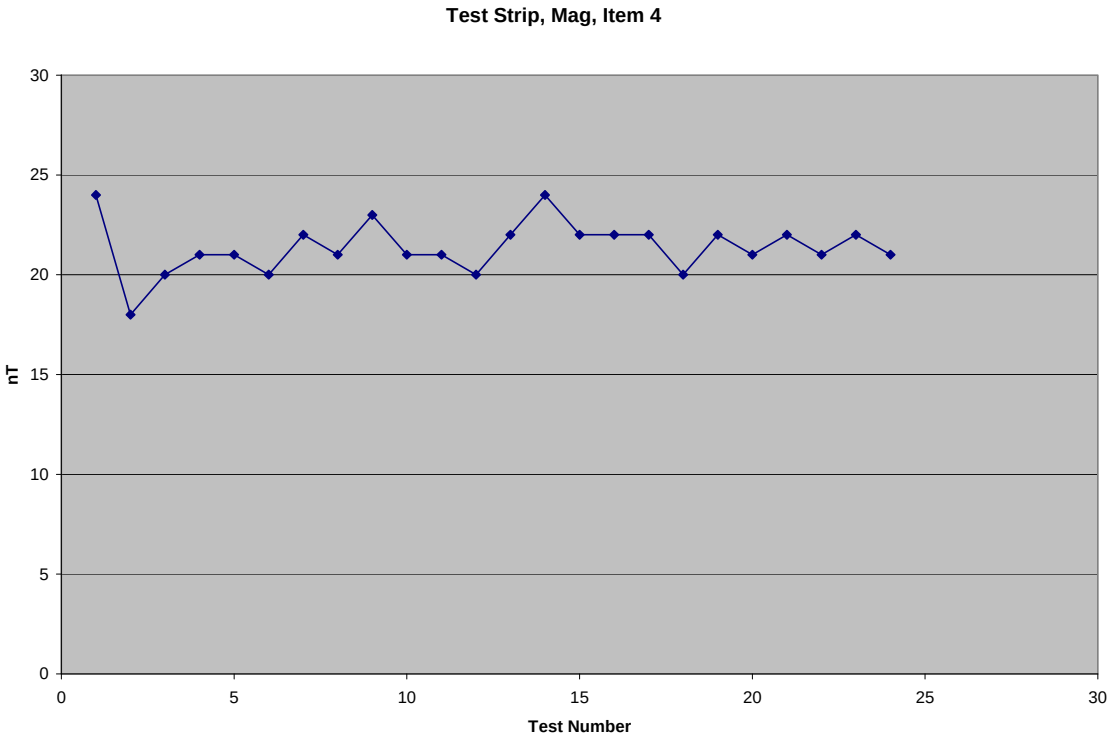


Figure 5: Calibration Strip Magnetometer Response for Item T-004 (60mm vert)

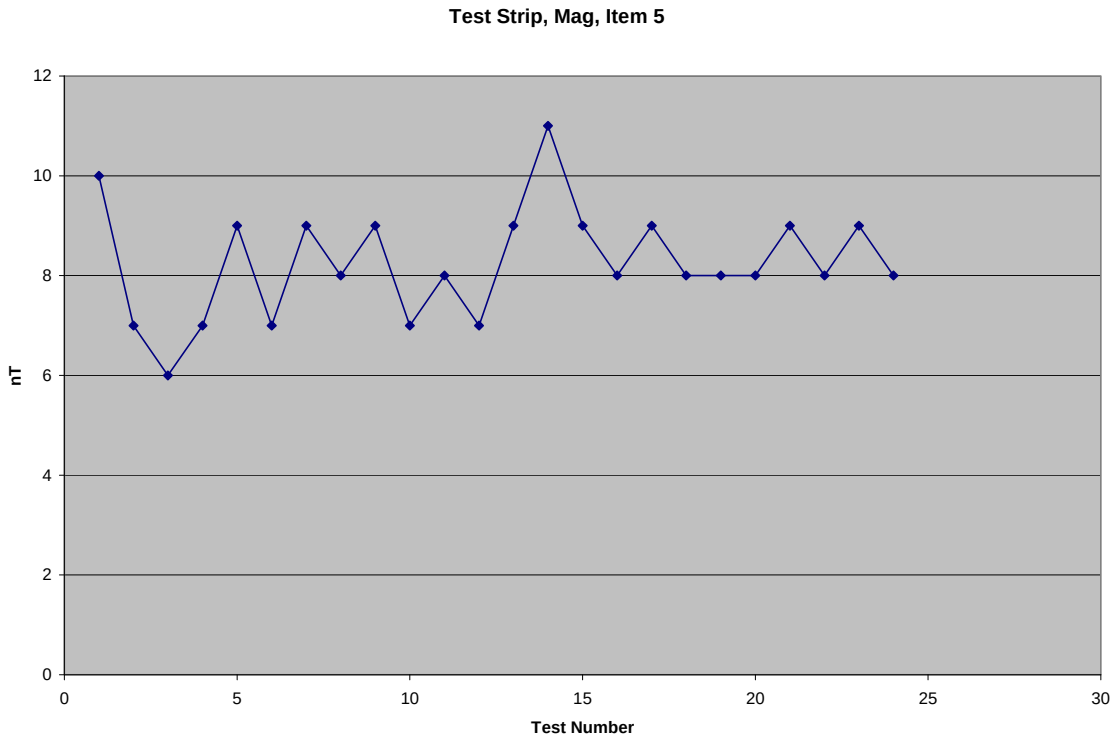


Figure 6: Calibration Strip Magnetometer Response for Item T-005 (60mm horiz)

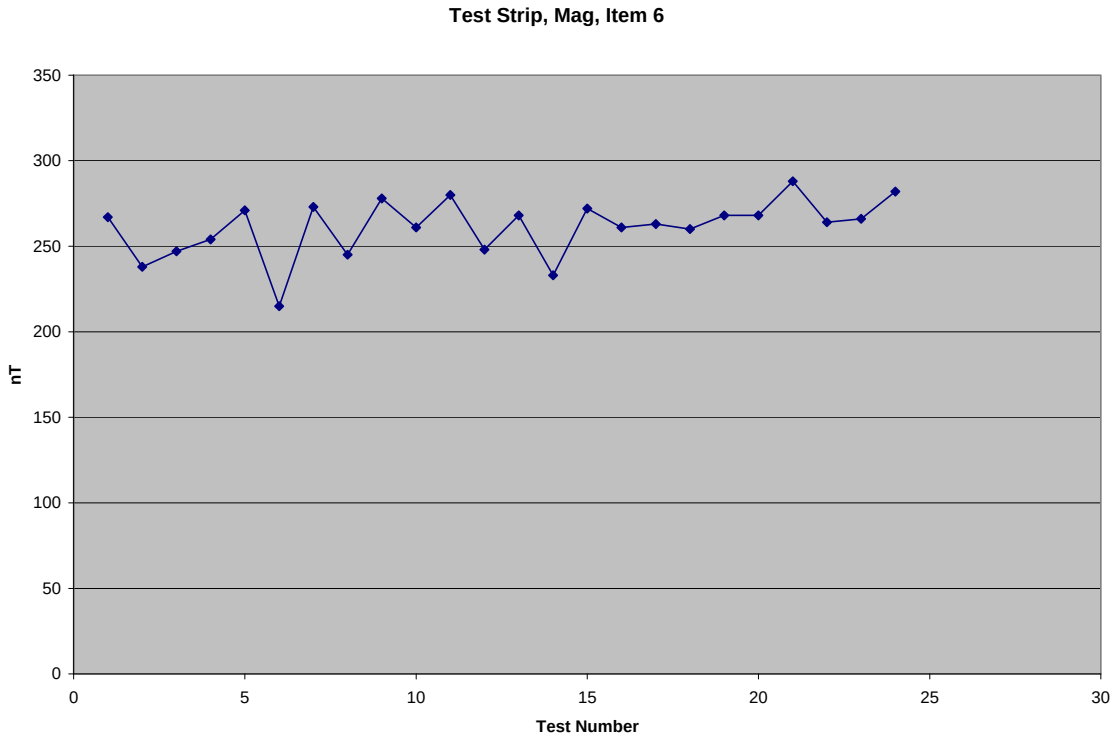


Figure 7: Calibration Strip Magnetometer Response for Item T-006 (4.2" mortar, vert)

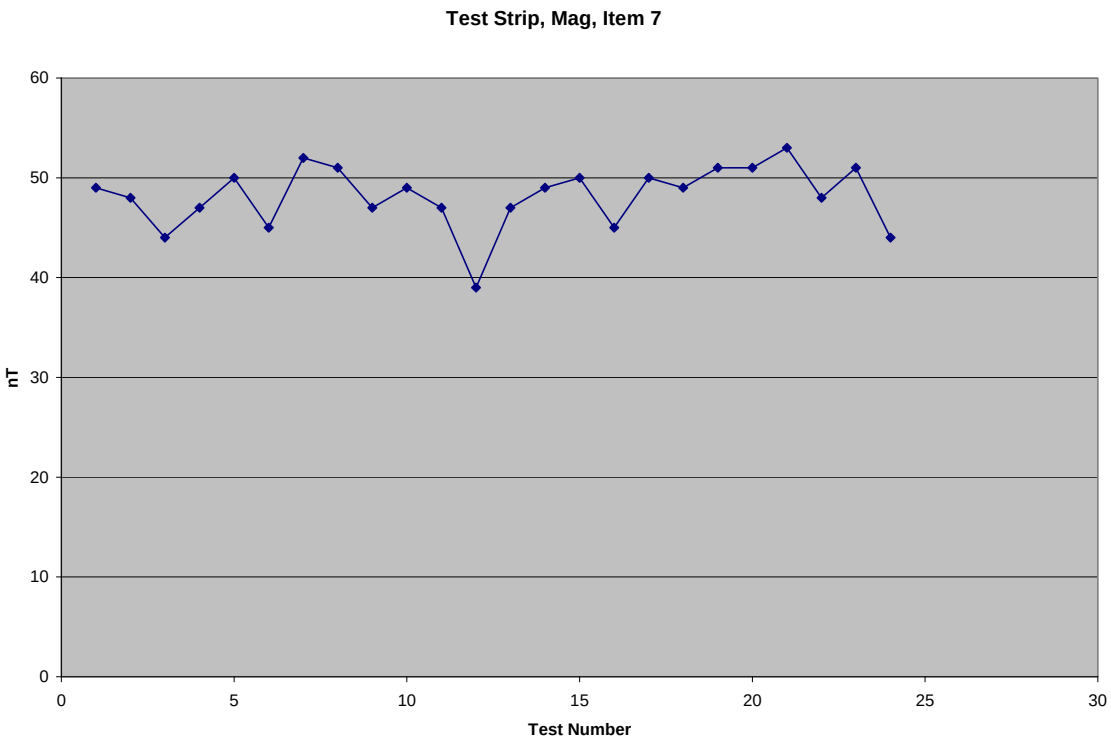


Figure 8: Calibration Strip Magnetometer Response for Item T-007 (4.2" mortar, horiz)

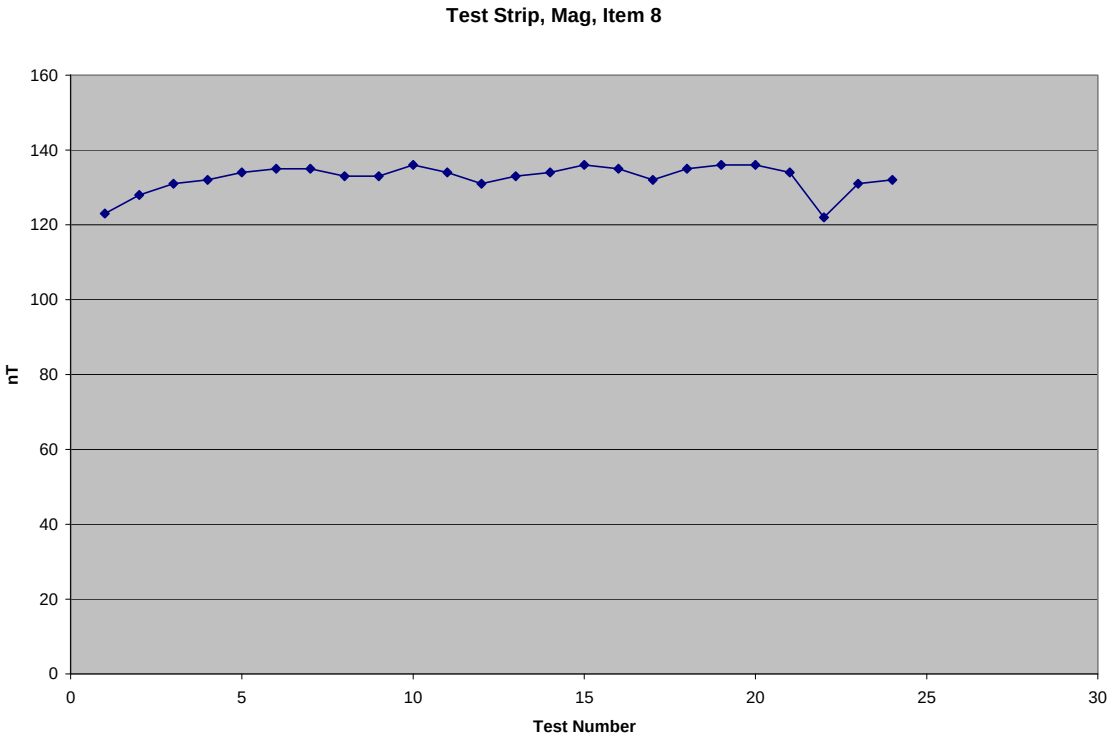


Figure 9: Calibration Strip Magnetometer Response for Item T-008 (2.36" rocket, vert)

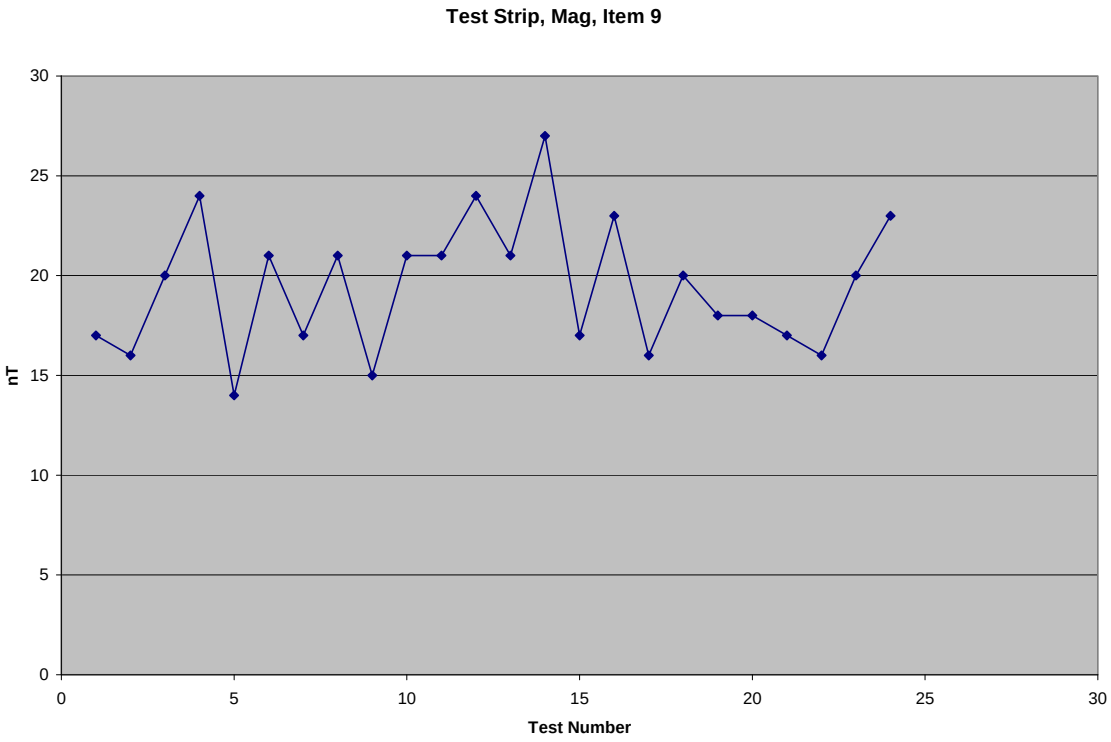


Figure 10: Calibration Strip Magnetometer Response for Item T-009 (2.36" rocket, horiz)

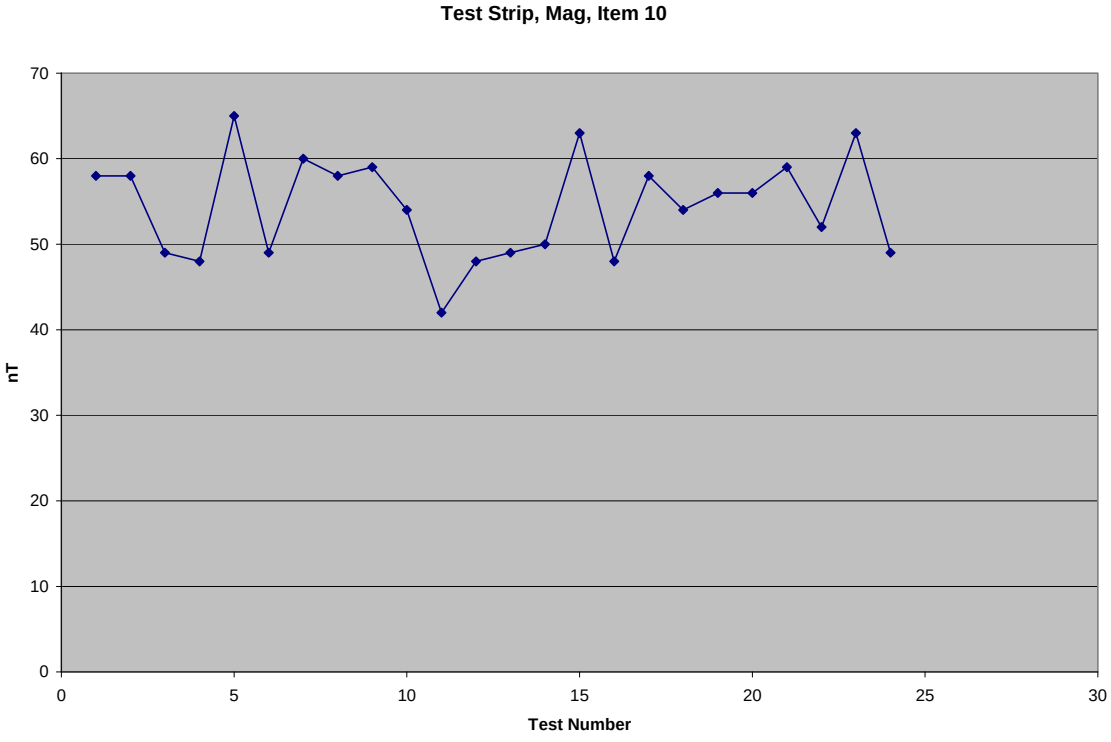


Figure 11: Calibration Strip Magnetometer Response for Item T-010 (shotput)

The graphs below show the calibration strip response consistency results for the EM61 data.

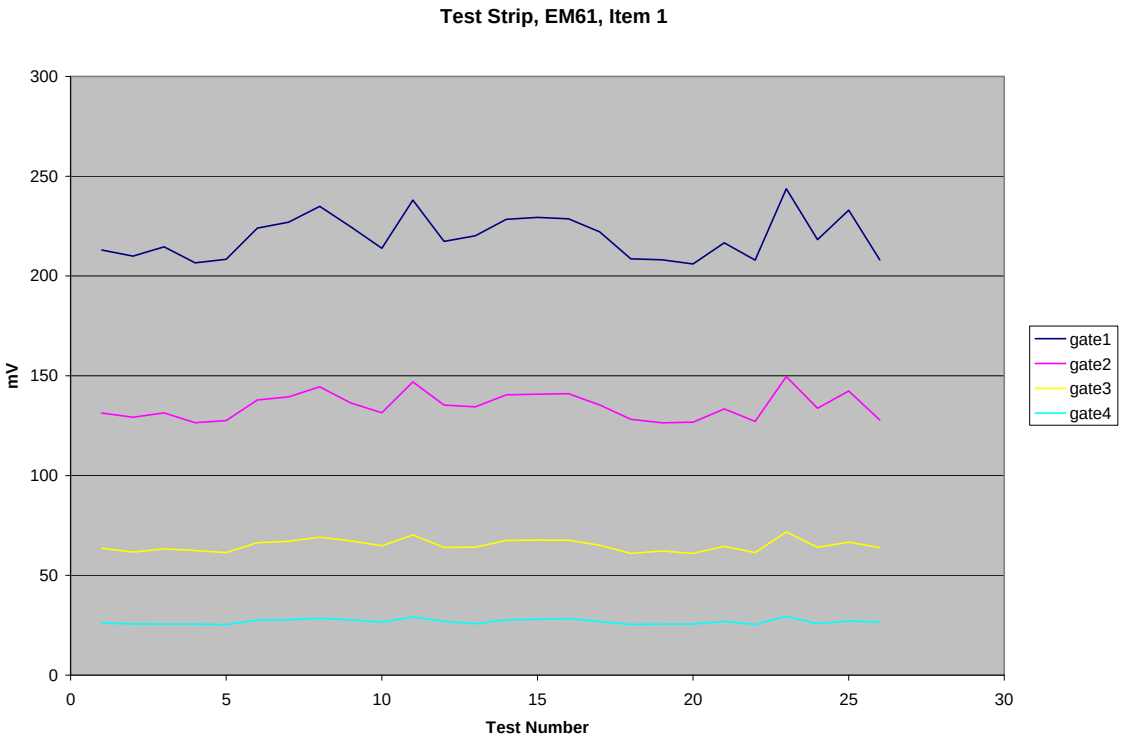


Figure 12: Calibration Strip EM61 Response for Item T-001 (Shotput)

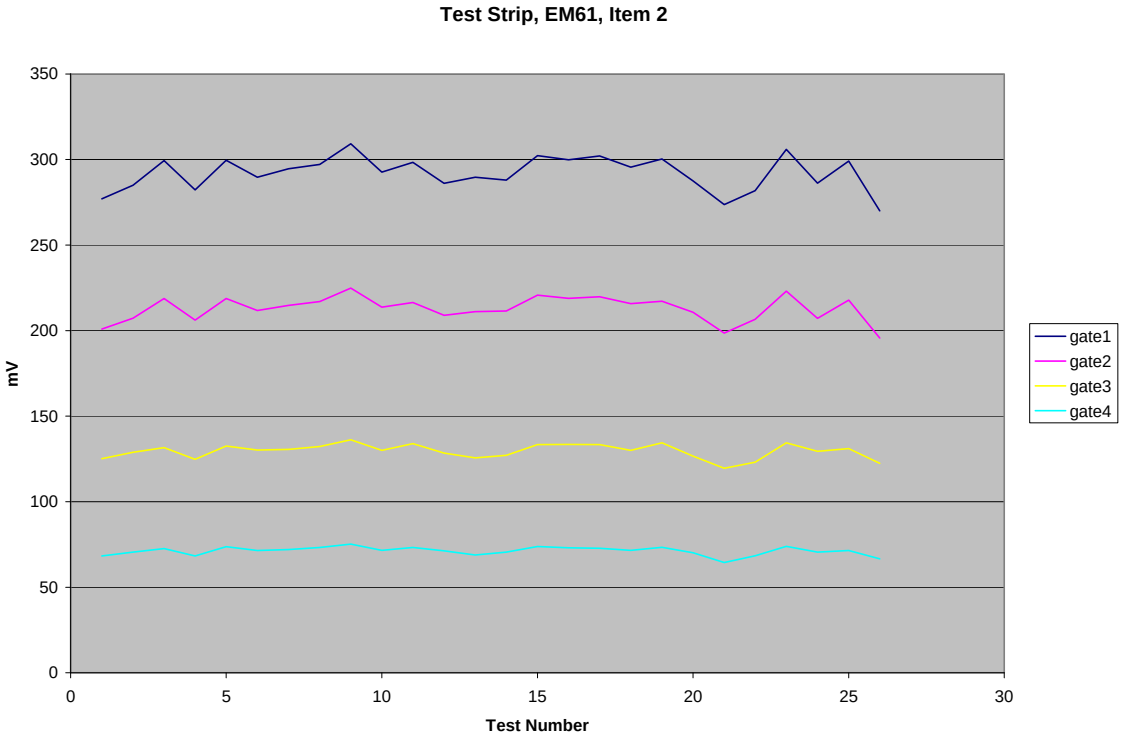


Figure 13: Calibration Strip EM61 Response for Item T-002 (81mm vert)

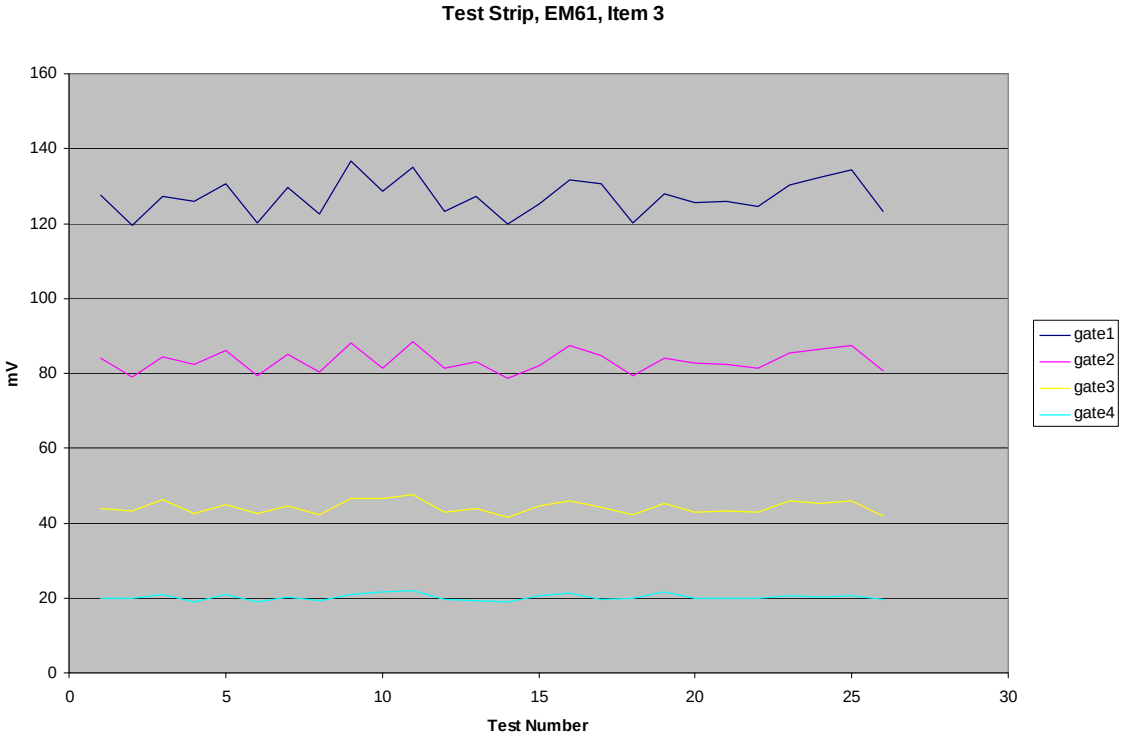


Figure 14: Calibration Strip EM61 Response for Item T-002 (81mm horiz)

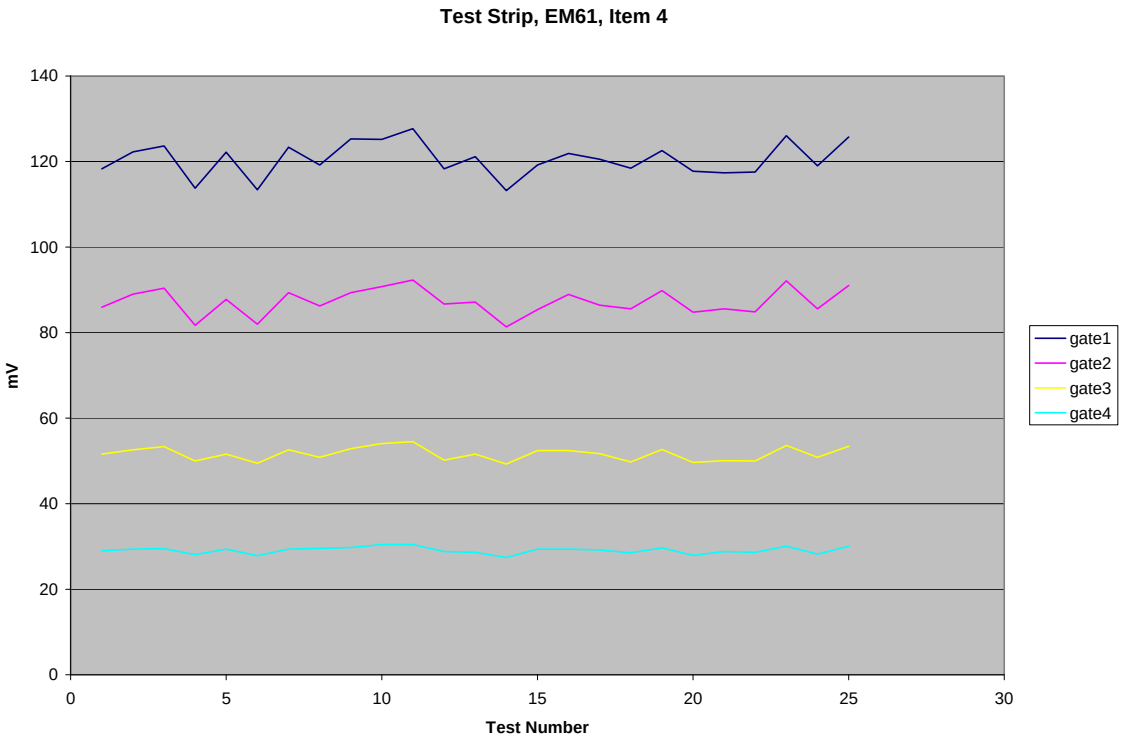


Figure 15: Calibration Strip EM61 Response for Item T-004 (60mm vert)

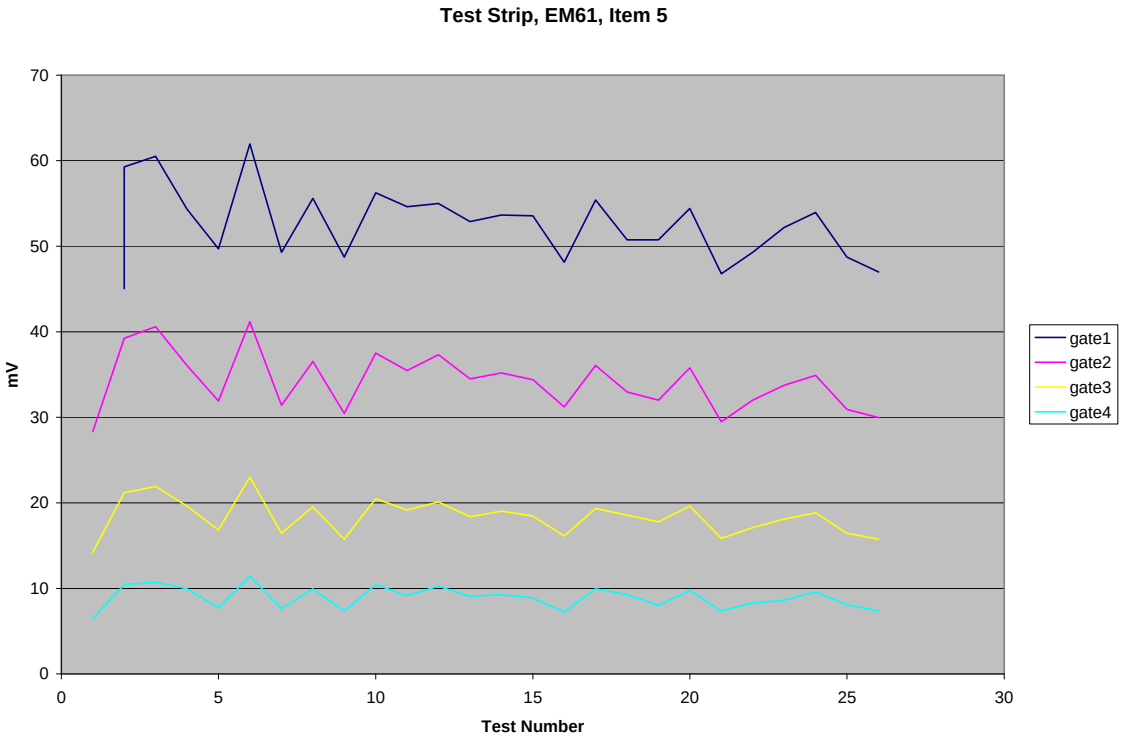


Figure 16: Calibration Strip EM61 Response for Item T-005 (60mm horiz)

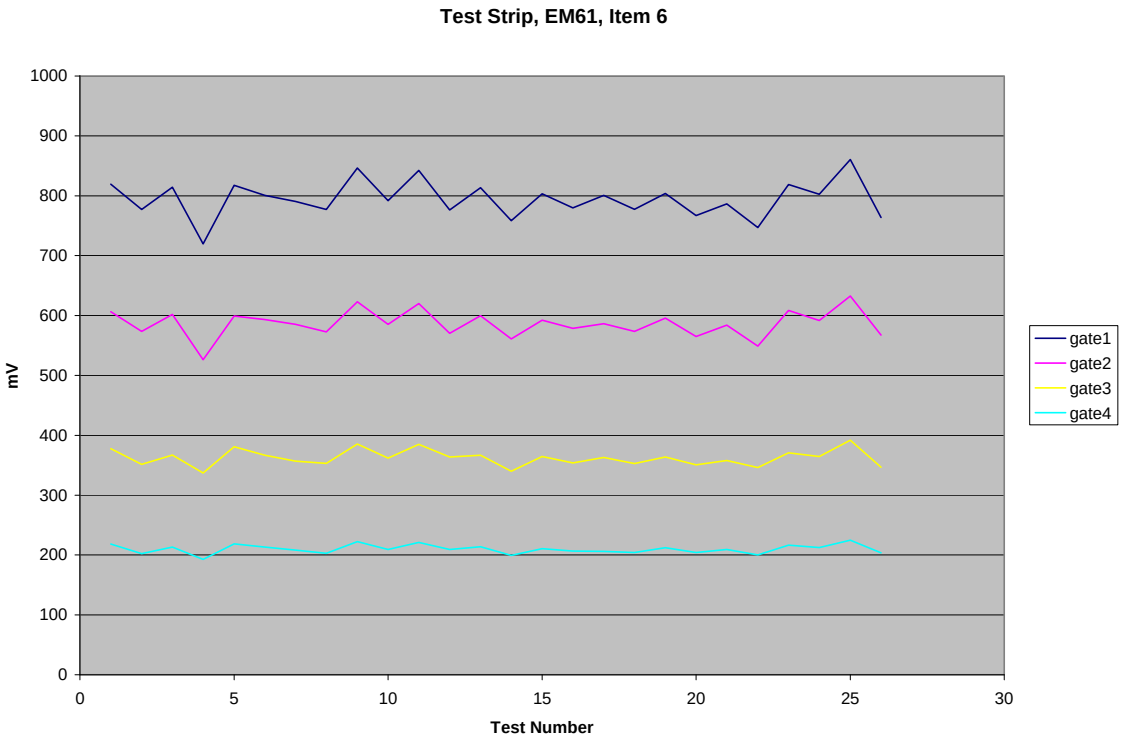


Figure 17: Calibration Strip EM61 Response for Item T-006 (4.2" mortar, vert)

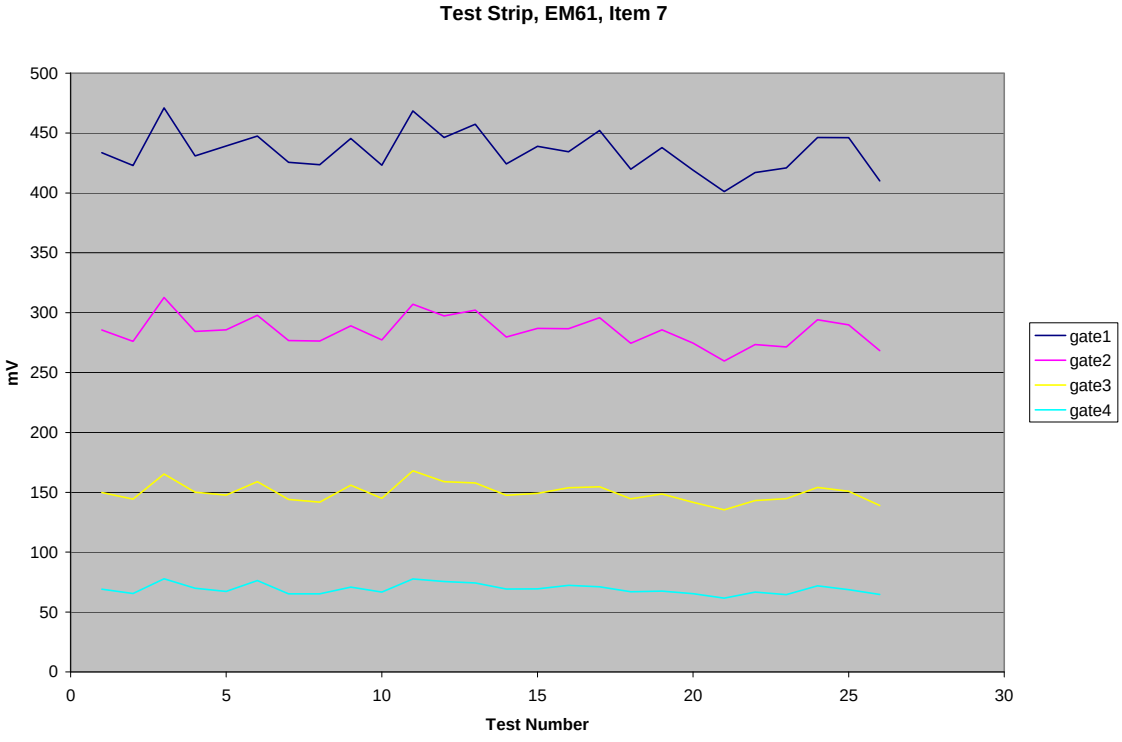


Figure 18: Calibration Strip EM61 Response for Item T-007 (4.2" mortar, horiz)

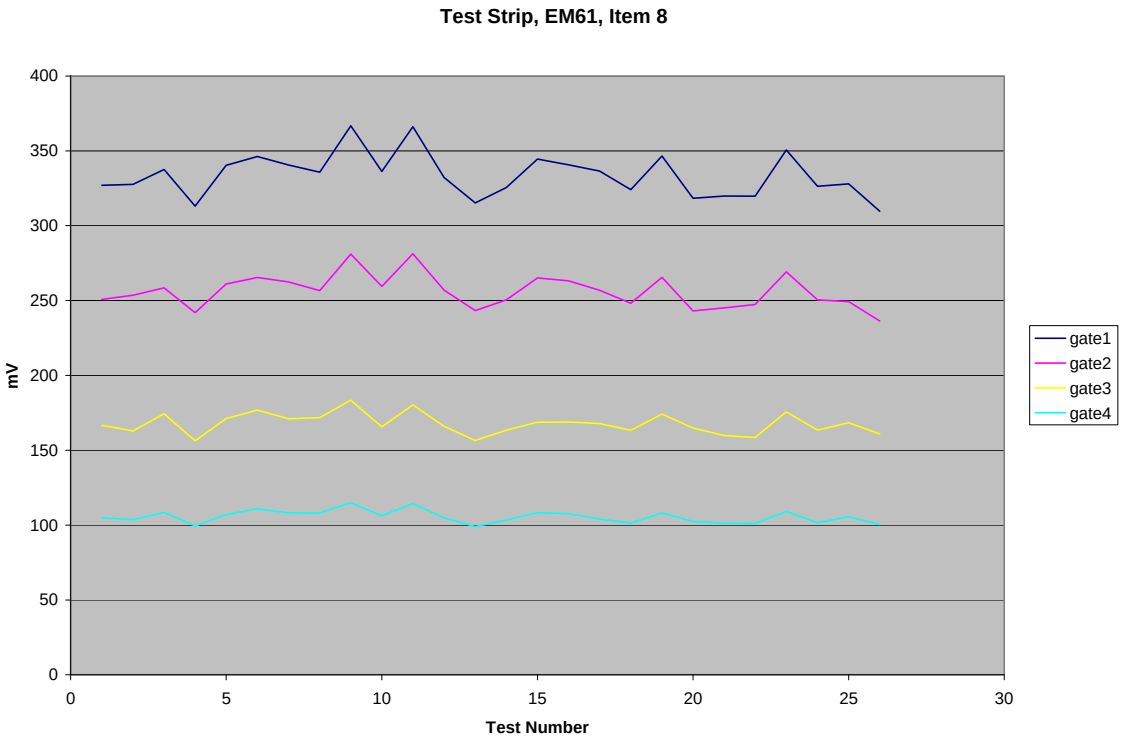


Figure 19: Calibration Strip EM61 Response for Item T-008 (2.36" rocket, vert)

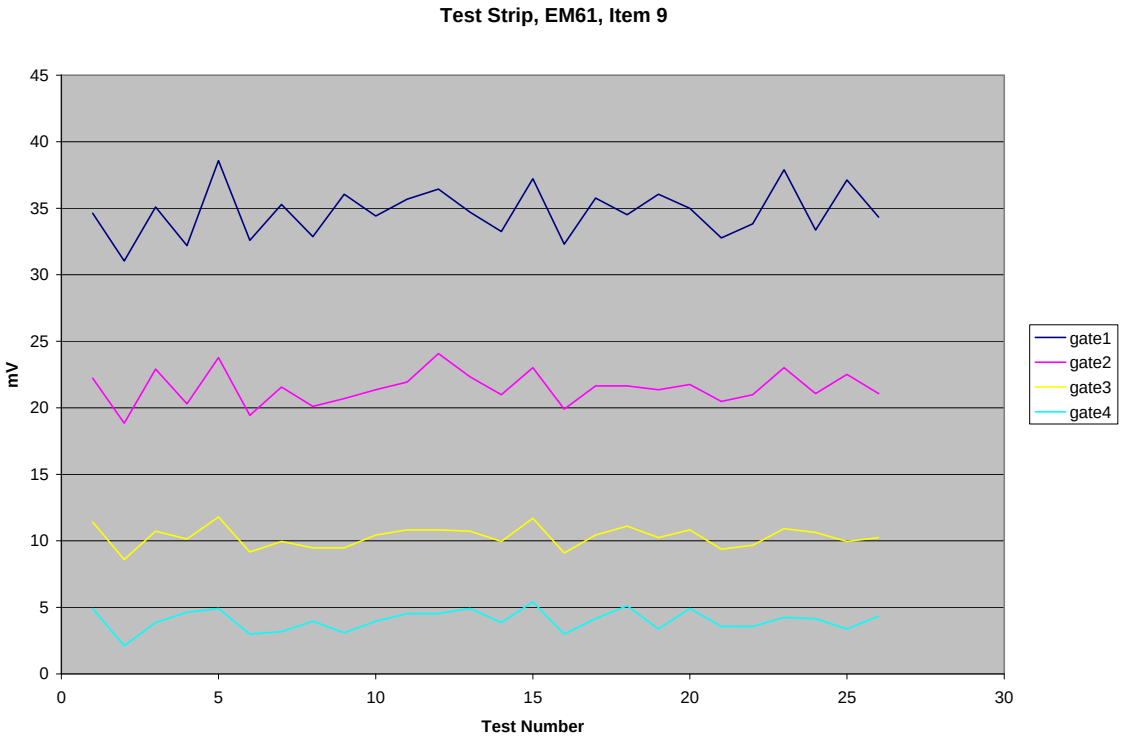


Figure 20: Calibration Strip EM61 Response for Item T-009 (2.36" rocket, horiz)

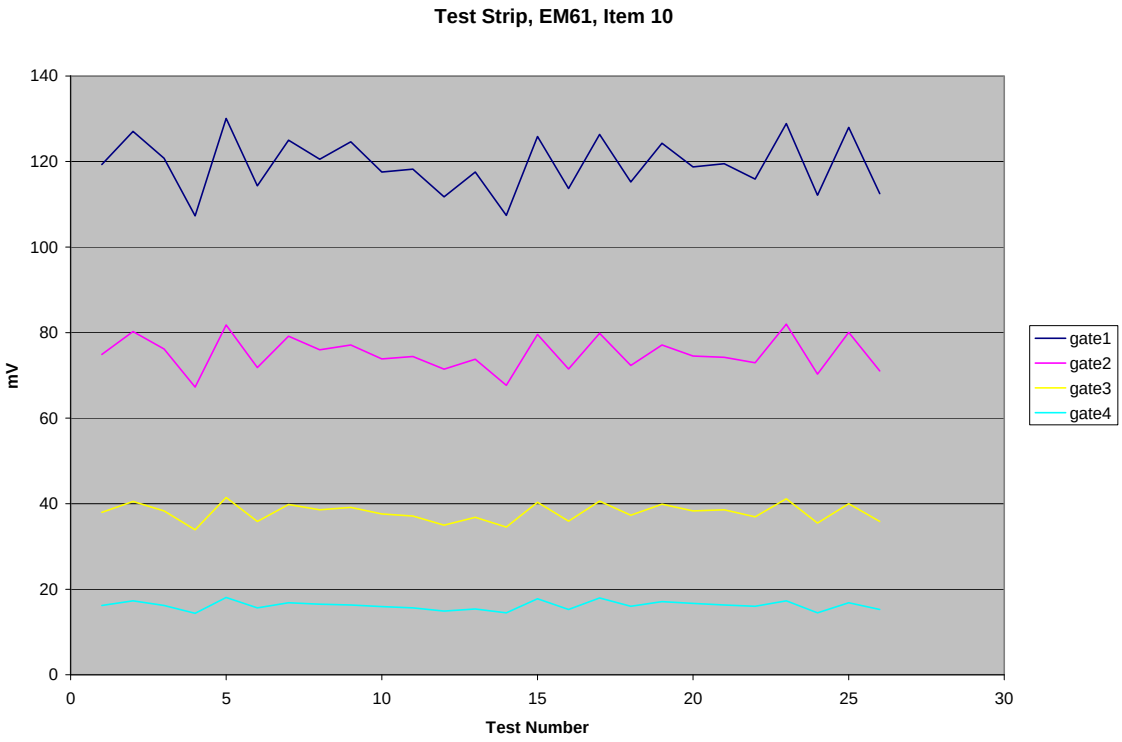


Figure 21: Calibration Strip EM61 Response for Item T-010 (shotput)

Training Pit Data

The training pit was populated with the objects and configurations required in the Demonstration Plan. With the repeat object and the empty survey, there were a total of 27 data sets acquired. These objects and orientations are enumerated in the table below. The physical emplacement and surveying of the objects was performed by NAEVA Geophysics.

2.36" rocket	
	22cm vertical nose up
	23cm 45 nose down
	25cm horizontal
	31cm 45 nose down
	34cm vertical nose down
	36cm horizontal
4.2" mortar	
	23cm 45 nose down
	24cm horizontal
	28cm vertical nose up
	31cm 45 nose down
	31cm vertical nose down
	36cm horizontal

60mm	
	17cm horizontal
	17cm vertical nose down
	18cm 45 nose down
	21cm vertical nose up
	22cm vertical nose down
	25cm 45 nose down
	25cm horizontal
81mm	
	23cm horizontal
	23cm horizontal repeat
	25cm 45 nose down
	28cm vertical nose up
	29cm vertical nose down
	36cm horizontal
shotput	30cm
empty	

There were several issues with the training pit. First, the pit location is in a very geologically active area, with a magnetic gradient of 150nT across the 20 meter length of the pit (the EM61 was immune to the gradient). Because of this gradient, we submitted an additional set of background leveled magnetometer training pit data to the Program Office (see section on background leveling below).

Second, the pit was in close proximity to a section of electric fence that ringed the site (see above section on the electric fence). The training pit was surveyed the first day on site, and large spikes (tens of millivolts) were noticed on the EM61 data. The pit was resurveyed later in the trip, and the spiking in the EM61 data was somewhat lower but still present. For completeness, both the first and second calibration pit sets of data were submitted to the Program Office.

Background Leveling of Training Pit Data

Leveling was performed in Geosoft Oasis Montaj using the Data Preparation | Data Correction | Drift Correction menu that is part of the UxProcess package. EM61 MkII data were corrected using a median filter 30 seconds long, and ignoring 10% of lowest values and 30% of highest values. This proved very effective. Magnetometer data were corrected using a median filter 60 seconds long, ignoring 30% of lowest values and 30% of highest values. This did not prove optimal, but better values could not be found (the site is very geologically active). For some reason, the median filter in Oasis appears to require these lowest and highest rejection values and does not seem able to de-median the data without them. Because of the high gradient in the training pit, in addition to leveling the data in Oasis and supplying it along with the unleveled data in the databases, we also applied our own de-median leveling tool to the magnetometer training pit data. This simply calculates a median for a given window (nominally six seconds long) and then

subtracts this median value from the data. These separate database files are labeled as "xxxx_mag_leveled.gdb" and contain *only* the leveled data. These files appear to do a better job of leveling the data across the object location in the middle of the training pit, but there are obvious artifacts at the ends of the traverses where the median values of the ends of the lines need to be calculated a different way. This is apparently not being correctly done, and this results in the profiles of the lines trending up or down for the first three seconds (half the window). Fortunately the middle portions of the lines (the portions over the object signature) are nicely de-trended by the de-median filter.

Data File Format

Oasis databases were submitted to the Program Office that contain:

- Easting and Northing (X and Y) values in UTM Zone 10N, meters
- Coil_number or Magnetometer number (always 1)
- Path_number (a line count)
- The time in seconds after midnight
- The unleveled and leveled data. For magnetometer data, the unleveled data and leveled data are each a single reading in nanotesla. For the EM61 MkII data, the unleveled and leveled data are each the four standard EM61 time gates from the lower coil.

Survey Grid Data

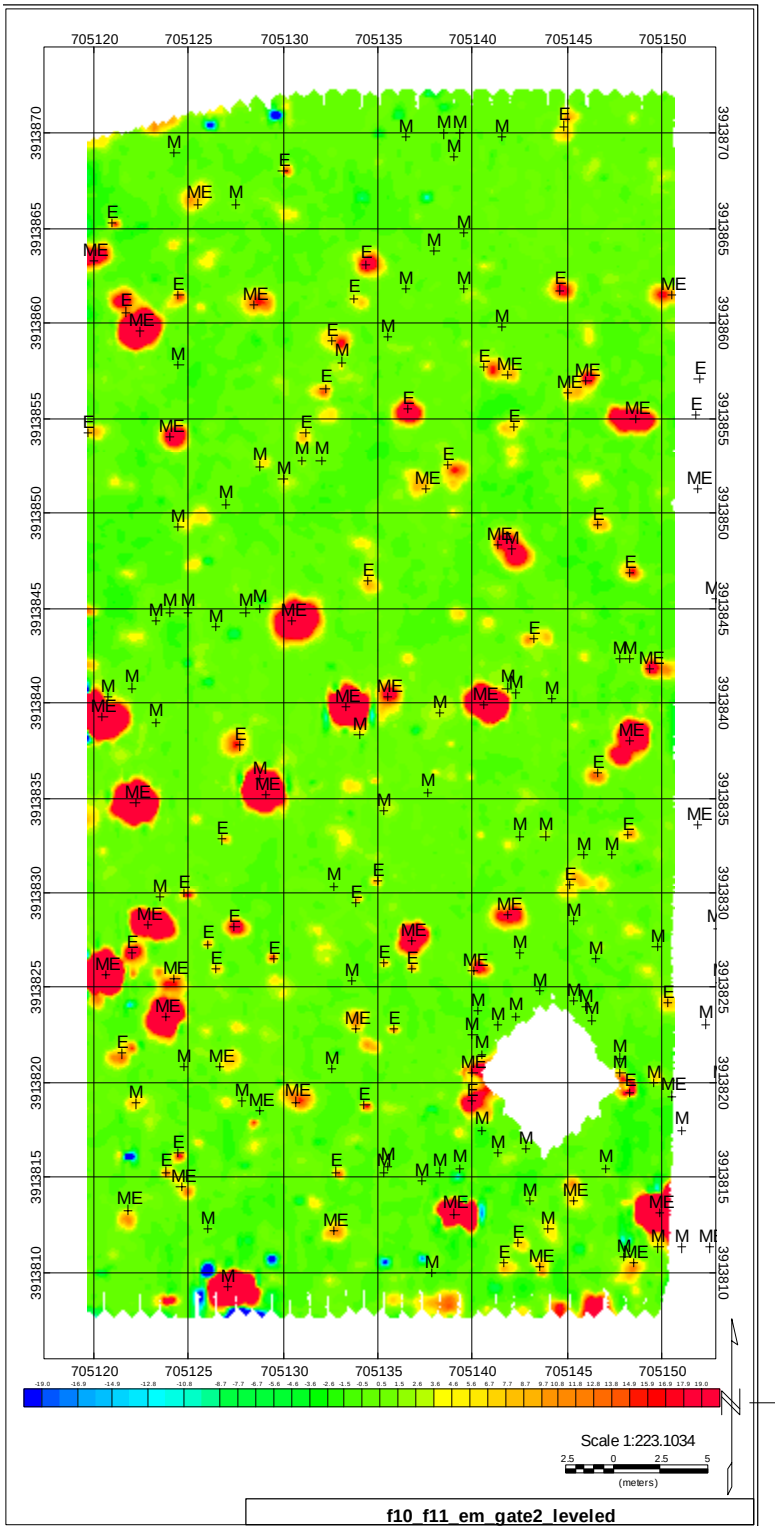
Oasis databases containing unleveled and leveled data over the survey grids were submitted to the Program Office. Names of the survey grid files are clearly labeled with grid square names, sensor type, and survey direction (e.g., "H10_H11_ns_mag.gdb"). Leveling was performed in Geosoft Oasis Montaj using the Data Preparation | Data Correction | Drift Correction menu that is part of the UxProcess package. EM61 MkII data were leveled using a median filter 30 seconds long, and ignoring 10% of lowest values 30% and of highest values. This proved very effective. Magnetometer data were leveled using a median filter 60 seconds long, ignoring 30% of lowest values and 30% of highest values. This was effective in removing geological trends in some of the grids, less effective in others.

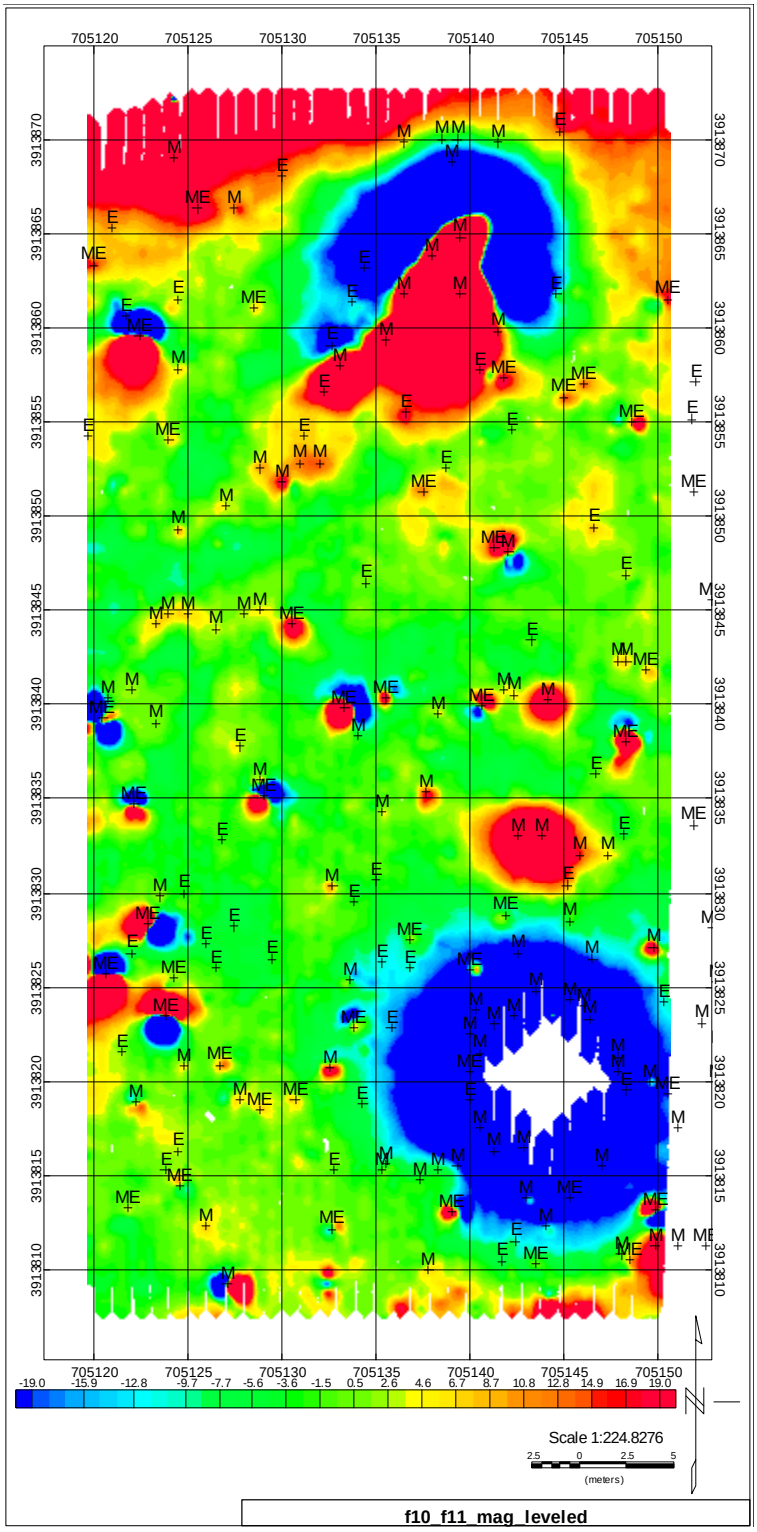
The grid data were submitted to the Program Office and slope-corrected by Nagi Khadr.

For reference, below are our grid images with our analyzed targets overlaid. Note that:

- All images are of non-slope-corrected data.
- All EM61 images are of leveled data from gate2 at a scale of +- 20mV.
- All magnetometer images are of *unleveled* magnetometer data (both leveled and unleveled data are contained in the database). Magnetometer images are displayed at a scale of +- 20nT except in certain grids where the geology created local gradients so strong that using this tight a display scale was useless.
- An "M" denotes a target detected by the magnetometer only, an "E" a target detected by the EM61 only, and an "ME" a target detected by both the magnetometer and the EM61. The target locations are for reference only; the

Program Office will distribute a final target list created from target lists generated with input from all data collection demonstrators.


705120
705125
705130
705135
705140
705145
705150
3913870
3913865
3913860
3913855
3913850
3913845
3913840
3913835
3913830
3913825
3913820
3913815
3913810
Scale 1:223.1034
2.5 0 2.5 5
(meters)
f10_f11_em_gate2_leveled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3913815
3913810
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:224.8276
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0
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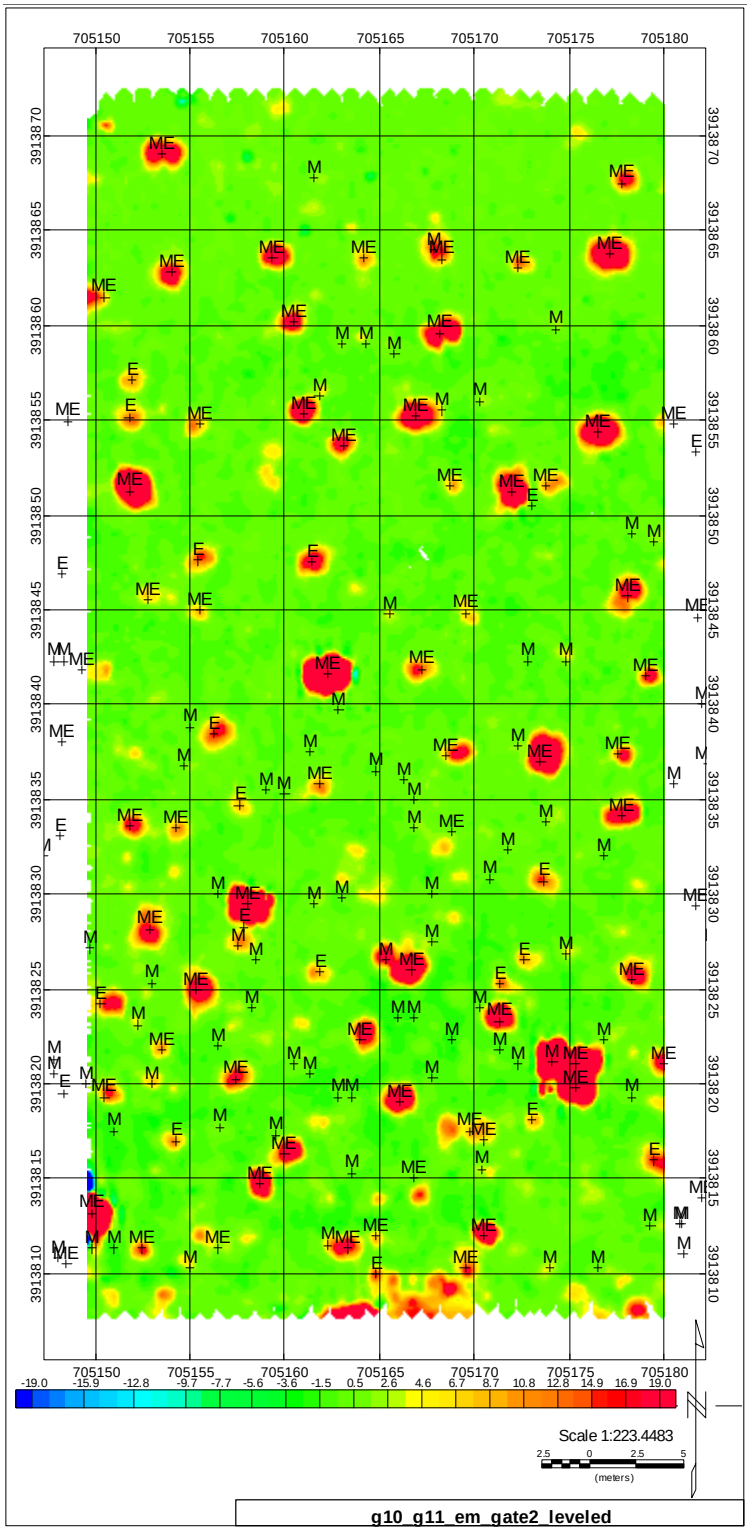
5
(meters)
f10_f11_mag_leveled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705170
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3913850
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3913830
3913825
3913820
3913815
3913810
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
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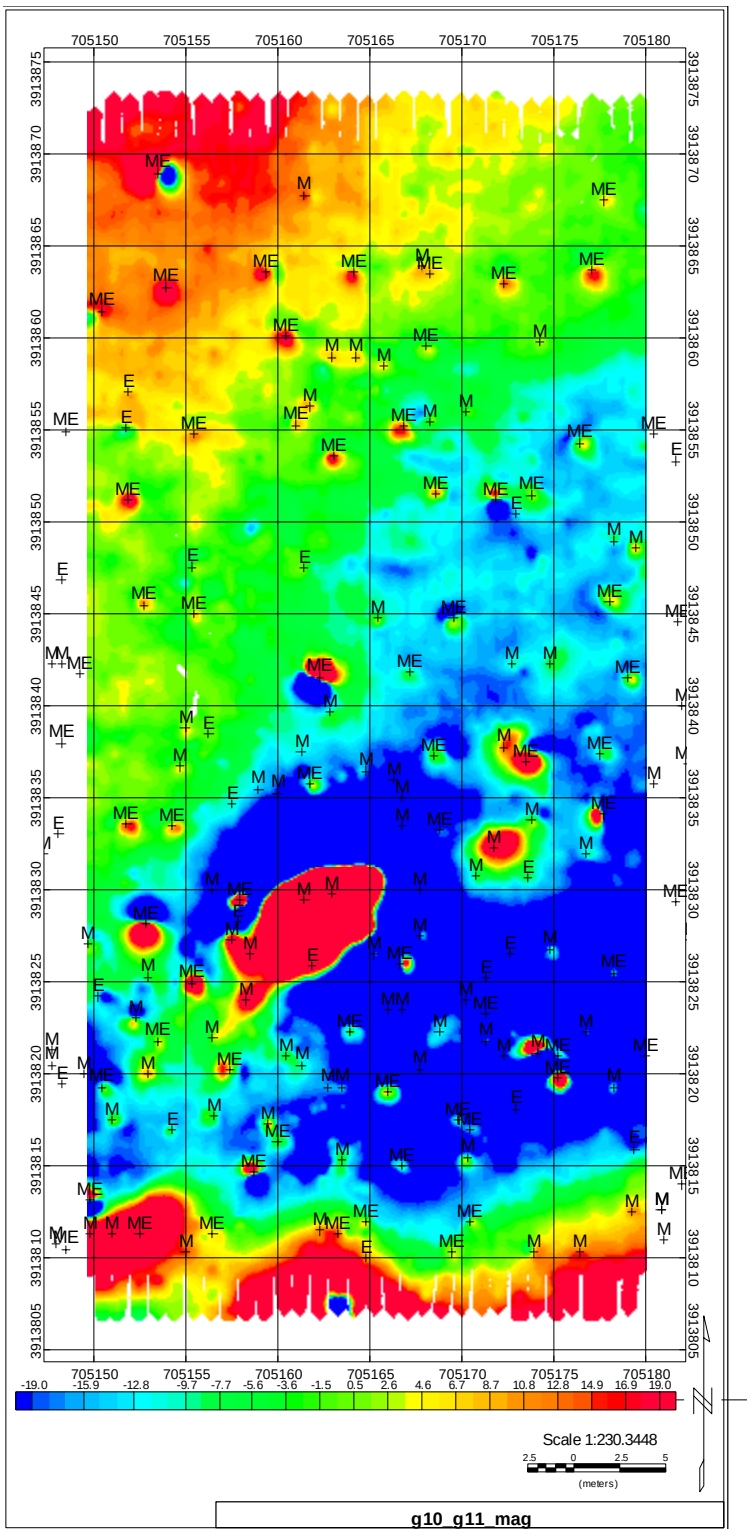
(meters)
g10_g11_em_gate2_leveled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3913855
3913850
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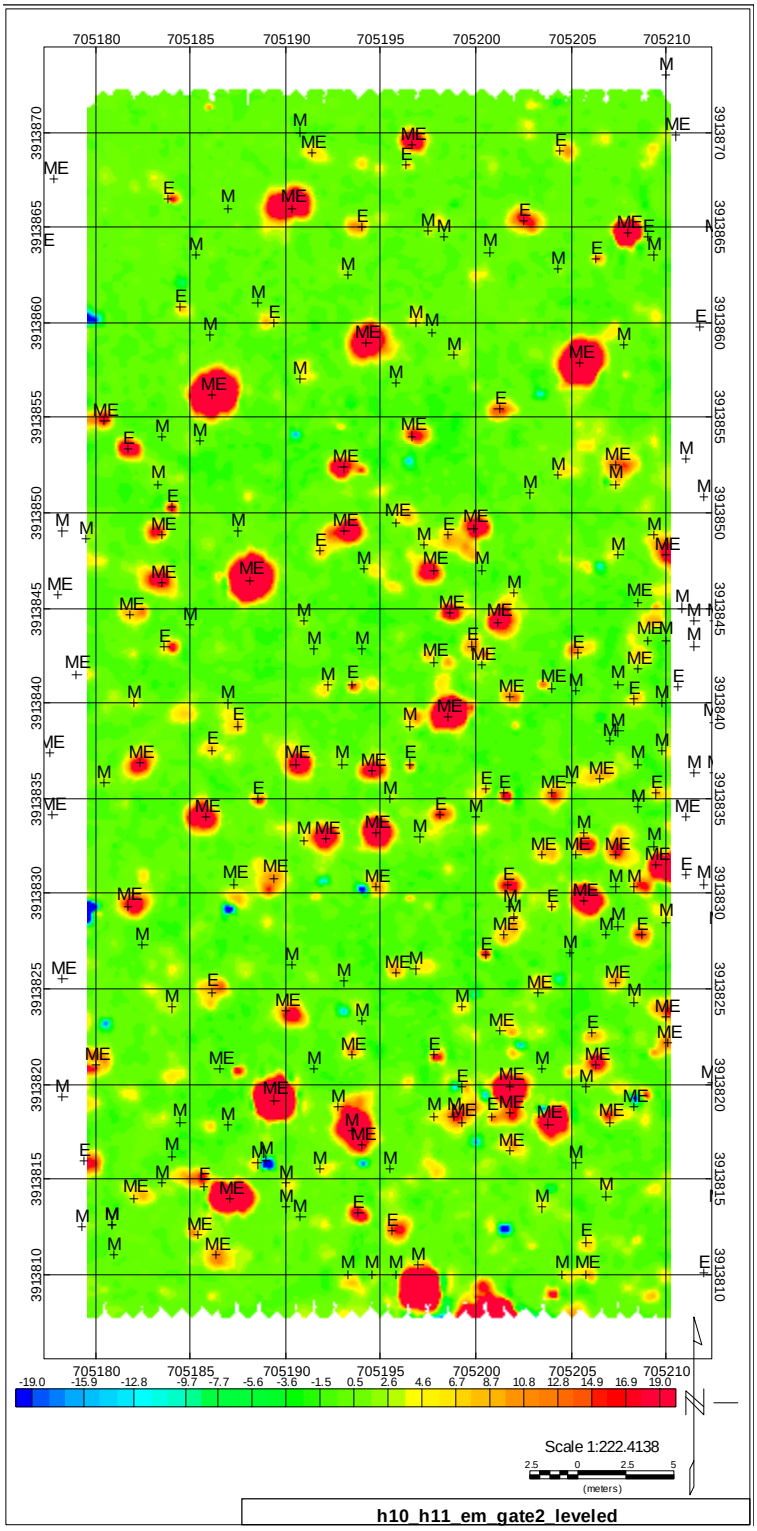
3913830
3913825
3913820
3913815
3913810
3913805
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:230.3448
2.5 0 2.5 5
(meters)
g10_g11_mag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3913845
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3913830
3913825
3913820
3913815
3913810
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:222.4138
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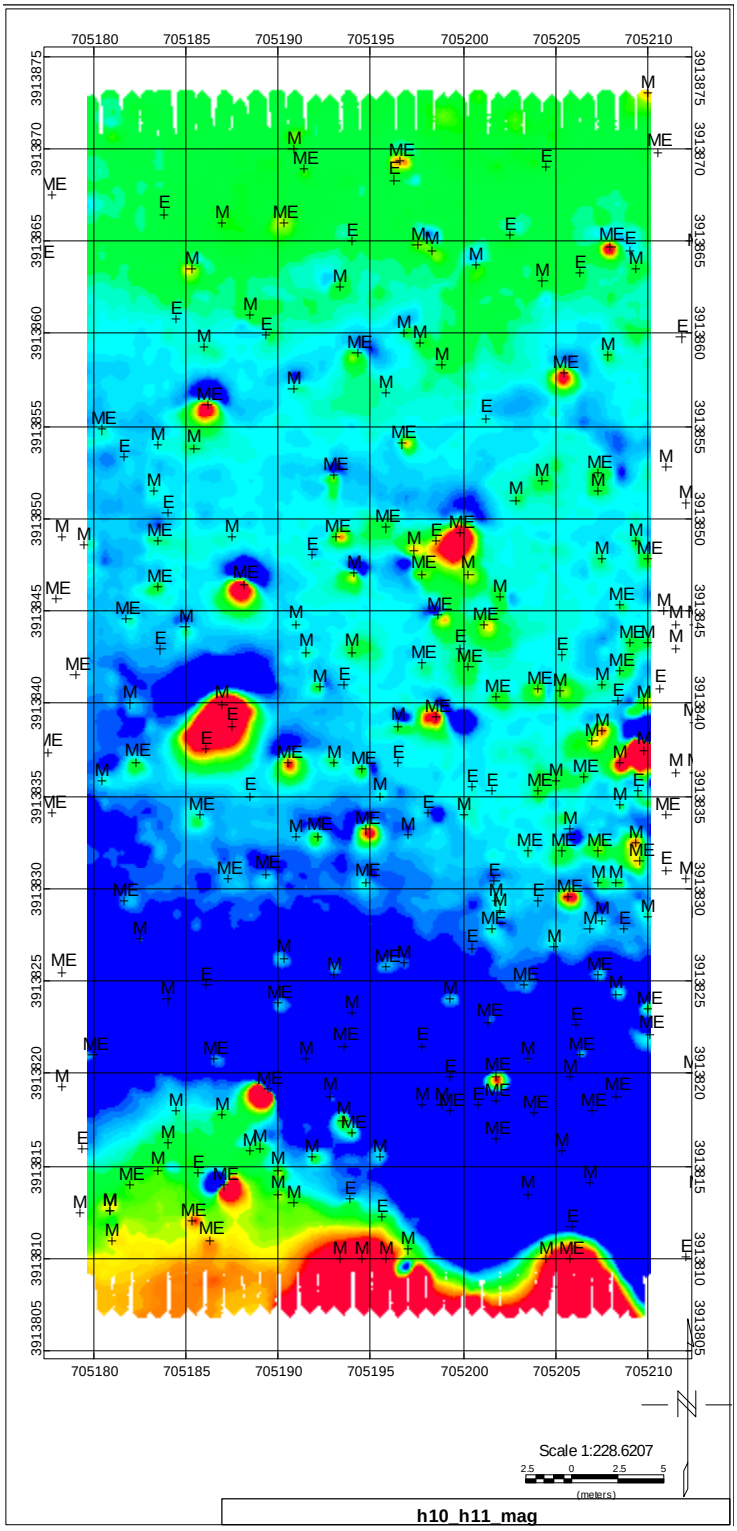
(meters)
h10_h11_em_gate2_leveled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3913835
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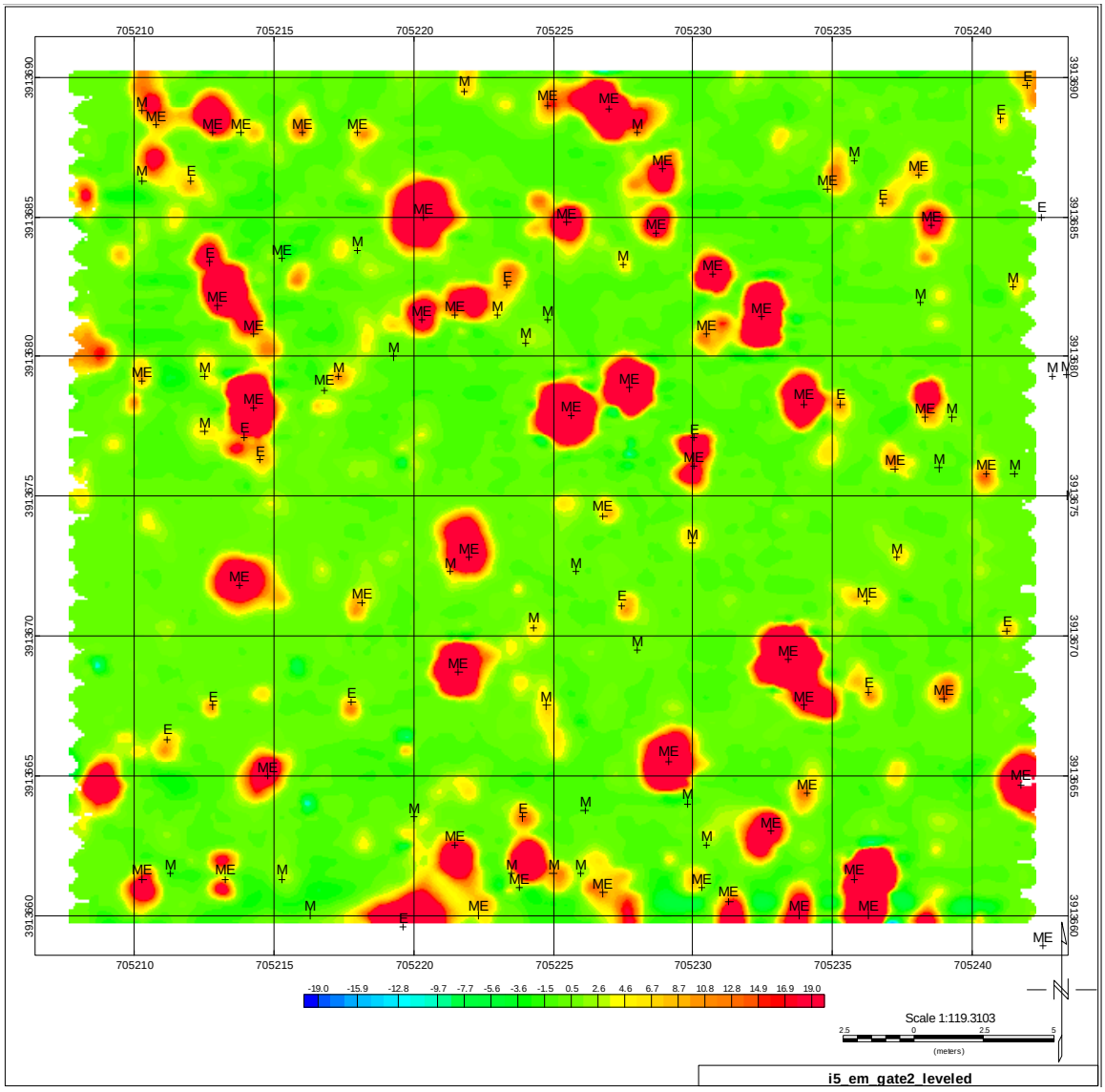
3913810
3913805
Scale 1:228.6207
2.5 0 2.5 5
(meters)
h10_h11_mag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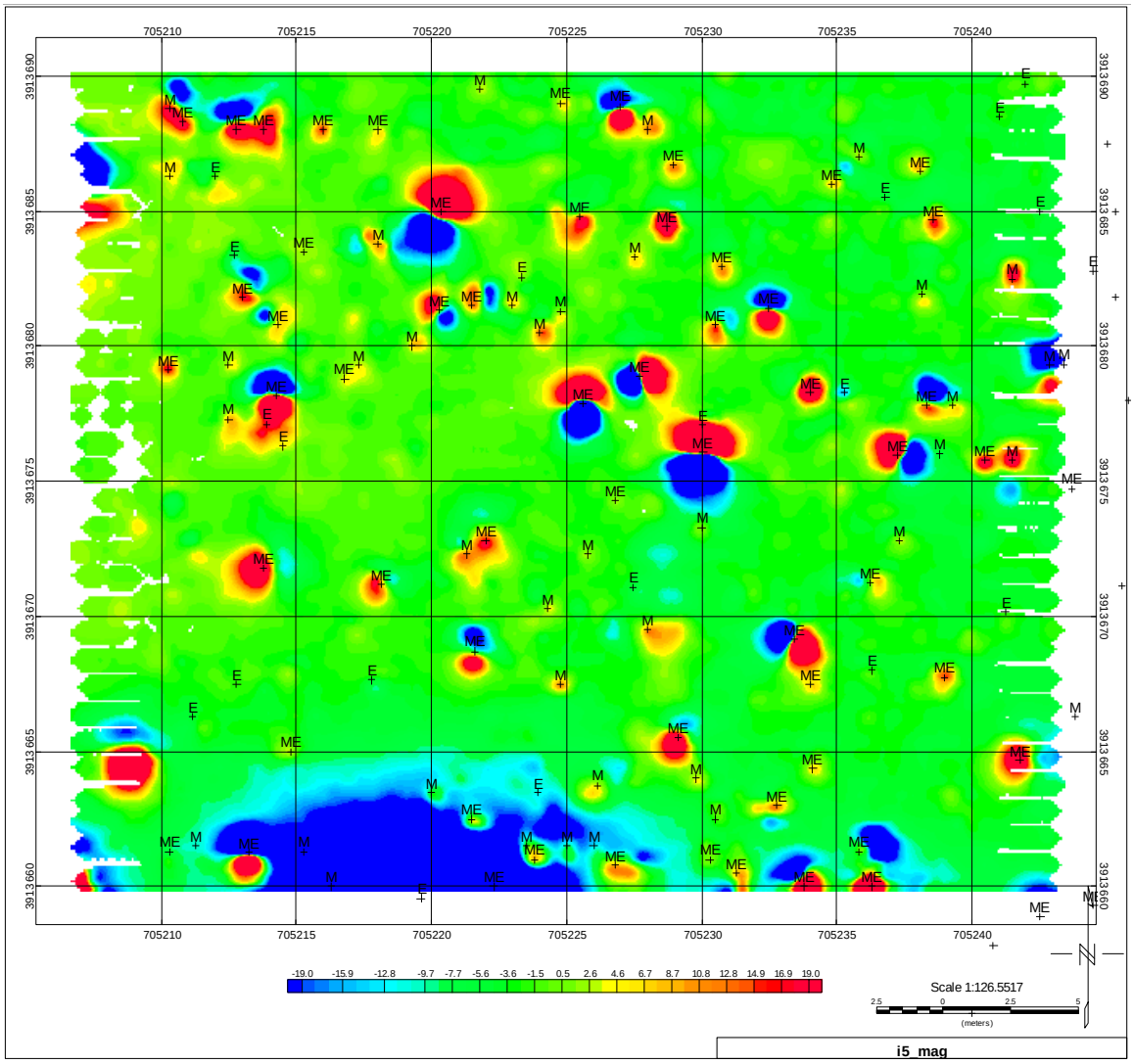
(meters)
i5_em_gate2_leveled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3913670
3913665
3913660
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Scale 1:126.5517
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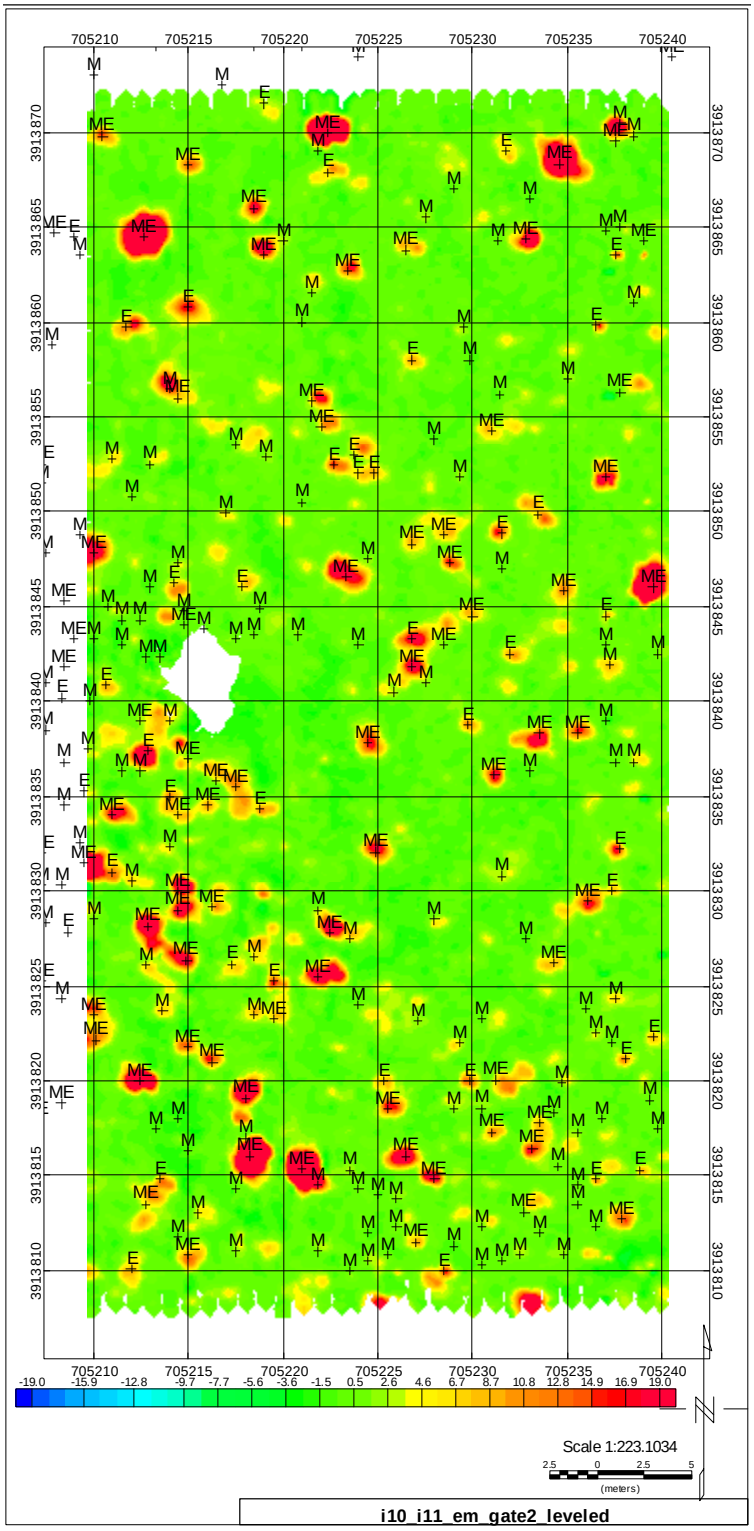
(meters)
i5_mag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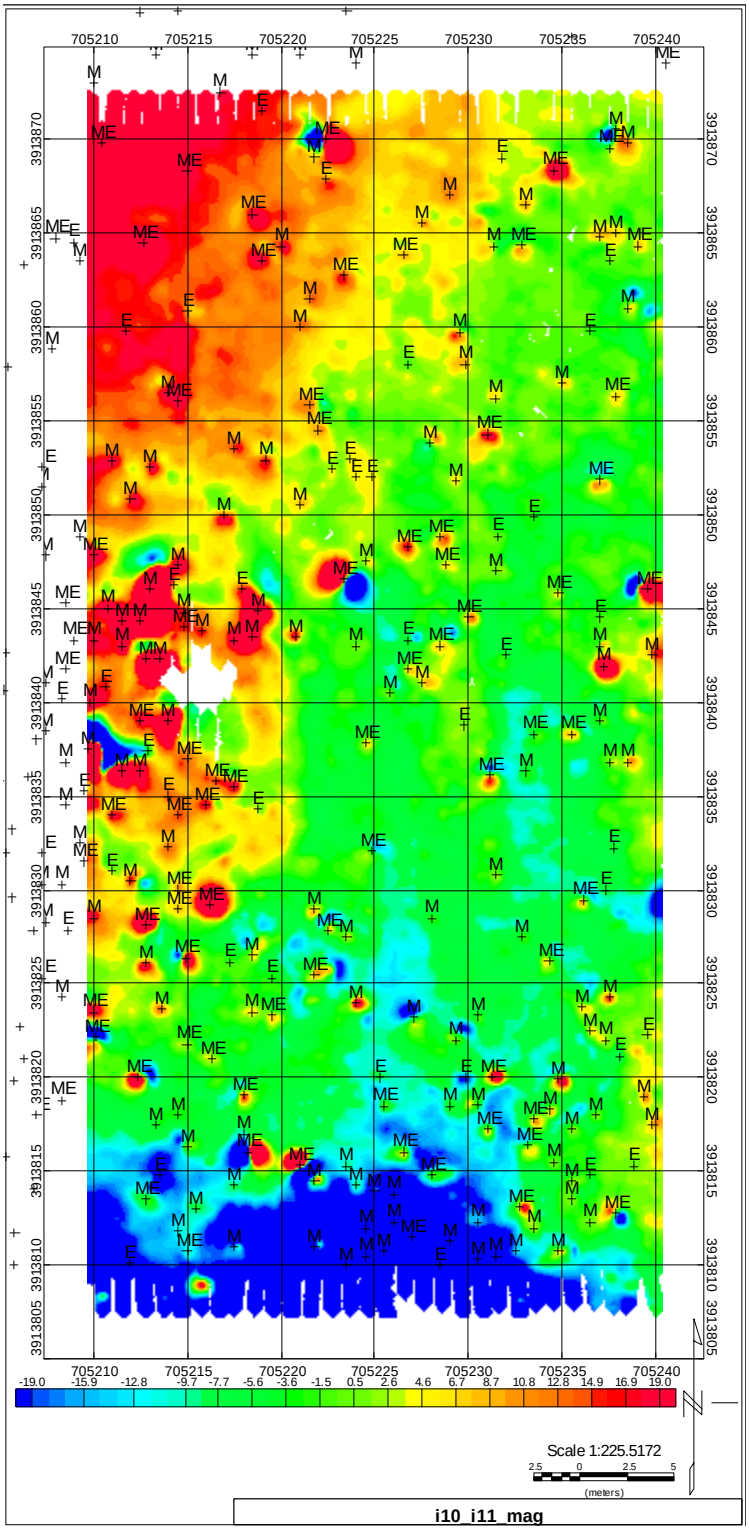
3913825
3913820
3913815
3913810
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:223.1034
2.5 0 2.5 5
(meters)
i10_i11_em_gate2_leveled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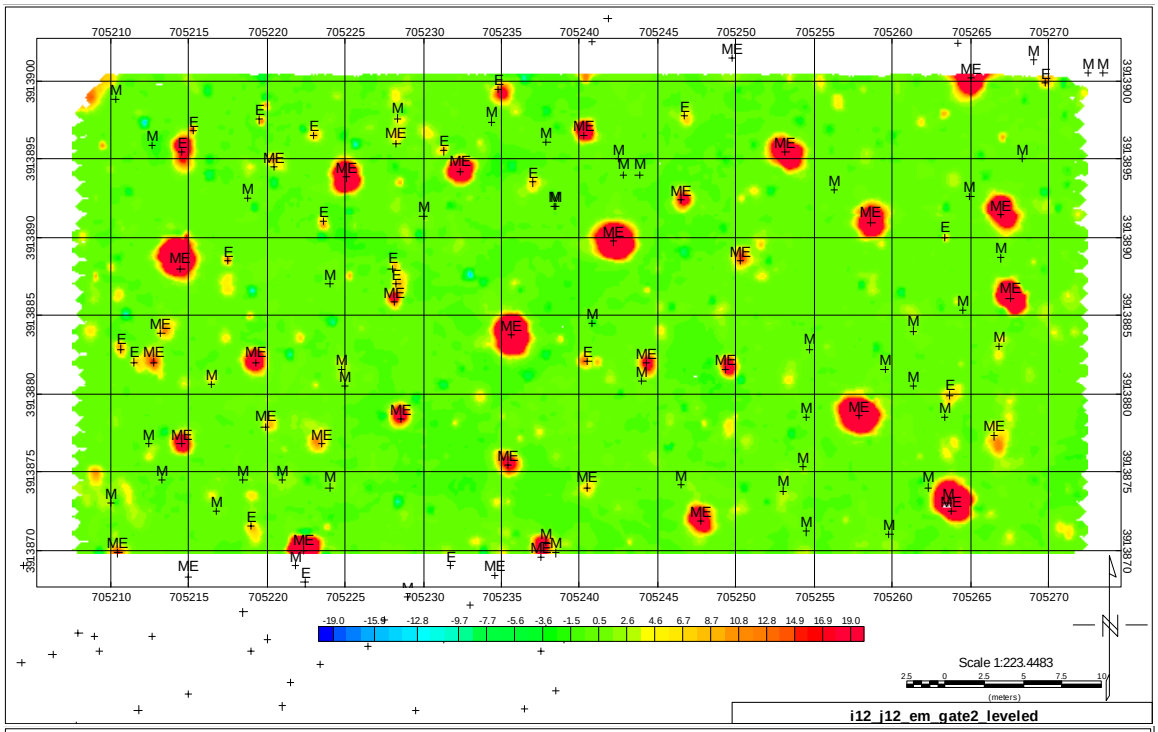
3913830
3913825
3913820
3913815
3913810
3913805
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:225.5172
2.5
0
2.5
5
(meters)
i10_i11_mag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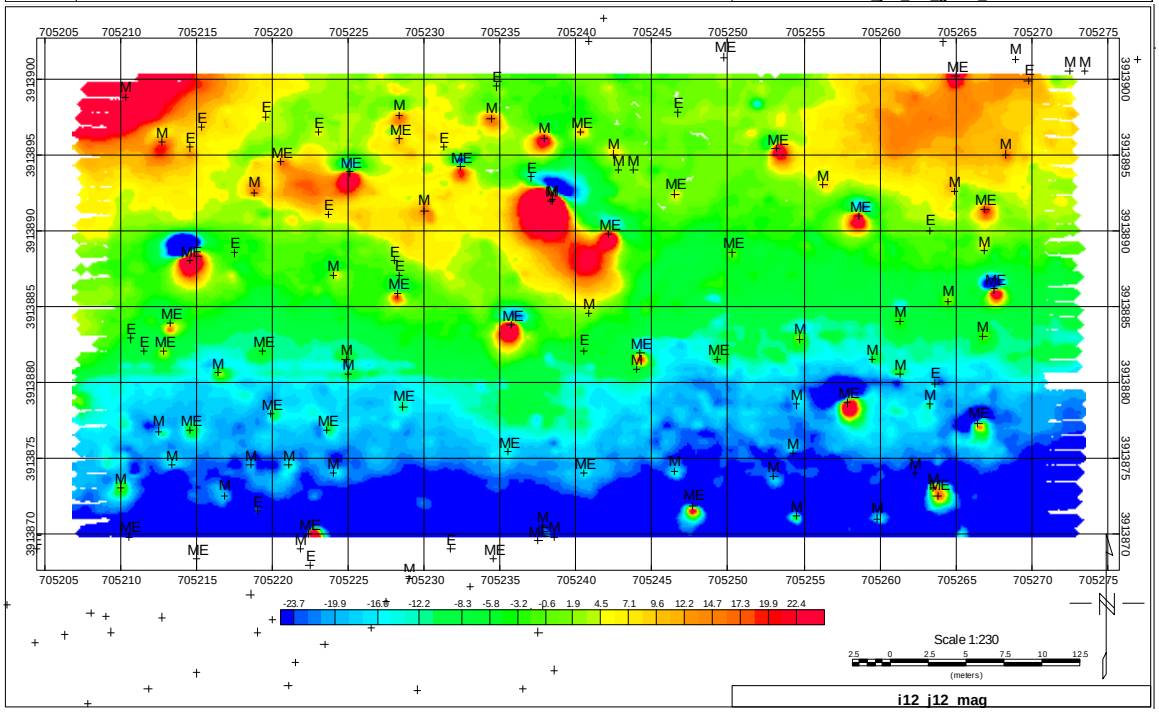
-19.0 -15.5 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:223.4483
2.5 0 2.5 5 7.5 10
(meters)
i12_j12_em_gate2_leveled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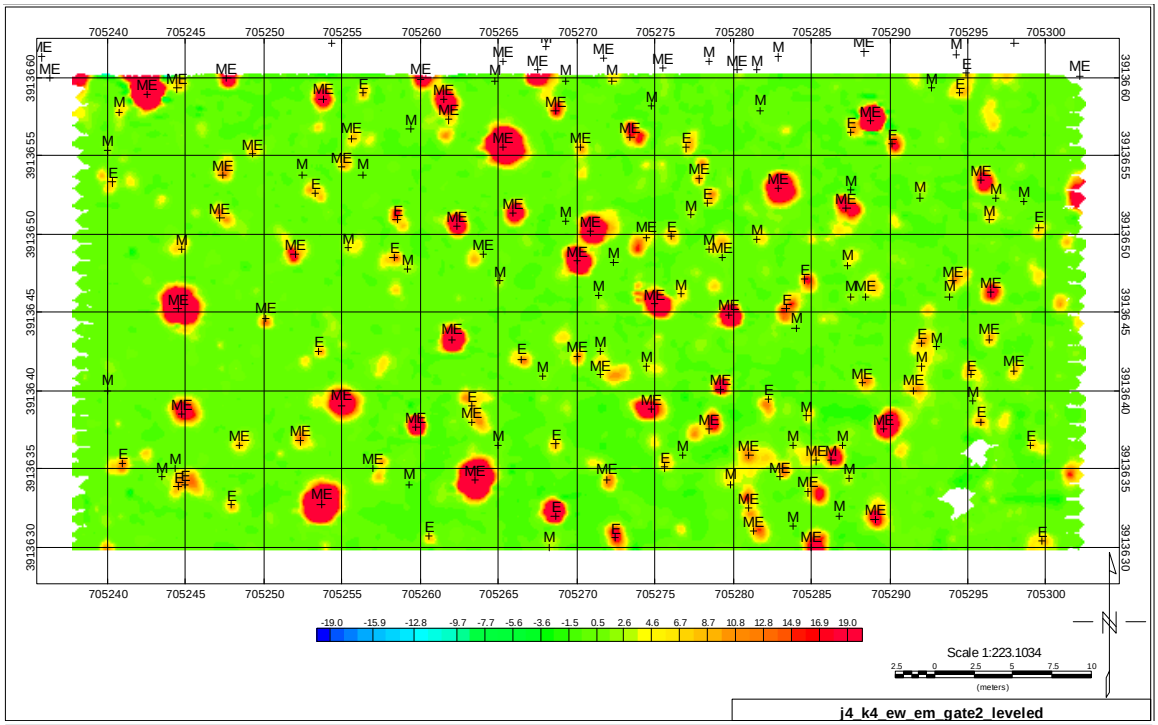
(meters)
i12_j12_mag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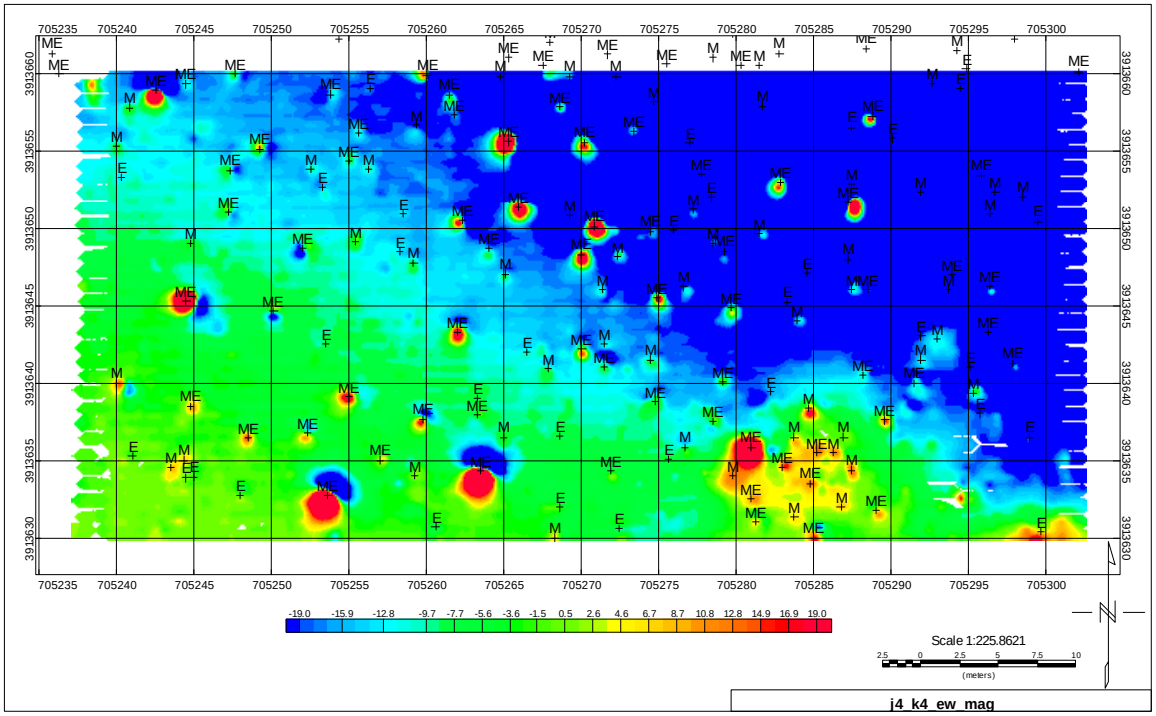
Scale 1:223.1034
2.5 0 2.5 5 7.5 10
(meters)
j4_k4_ew_em_gate2_leveled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-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
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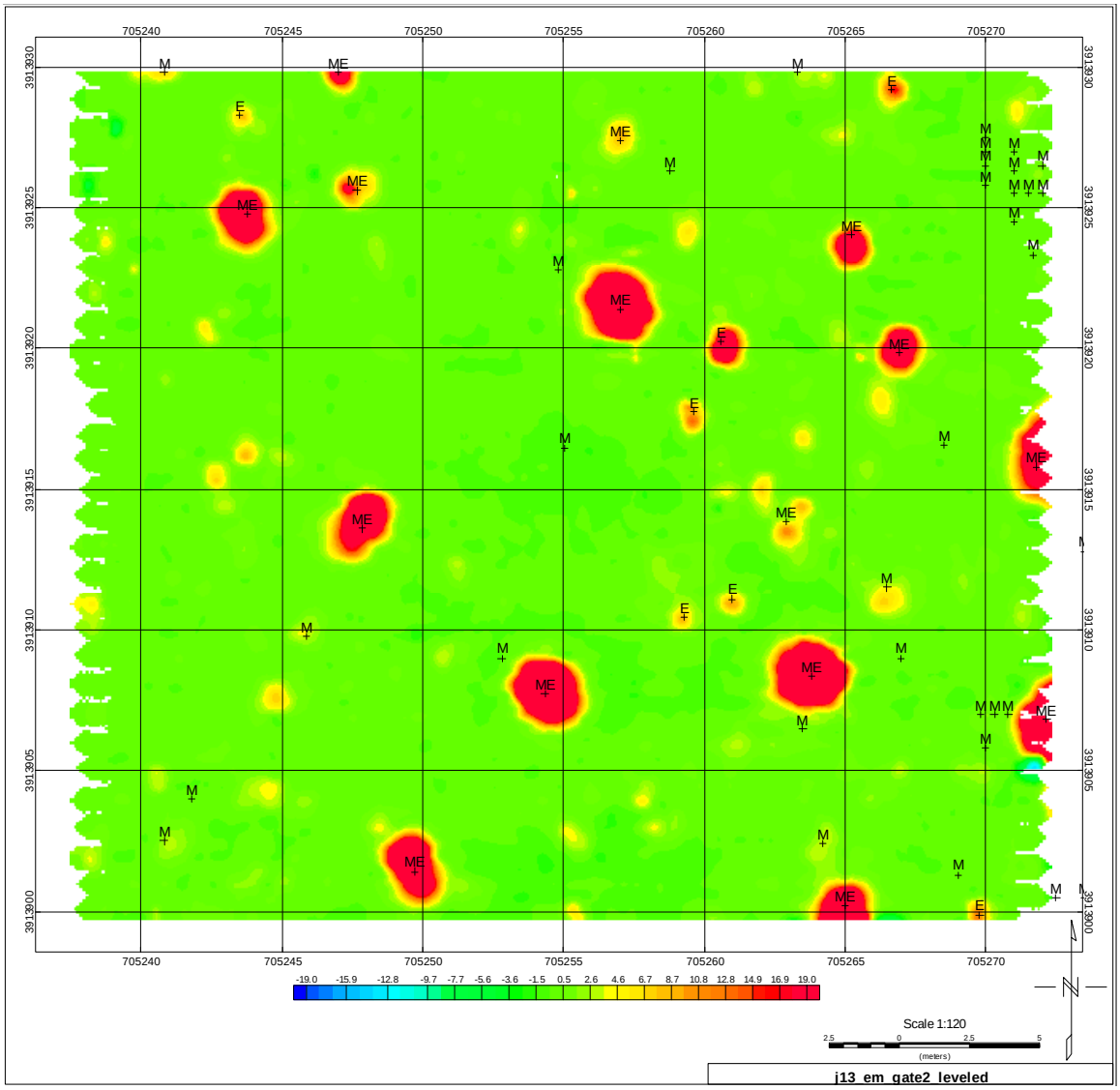
(meters)
j4_k4_ew_mag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3913905
3913900
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
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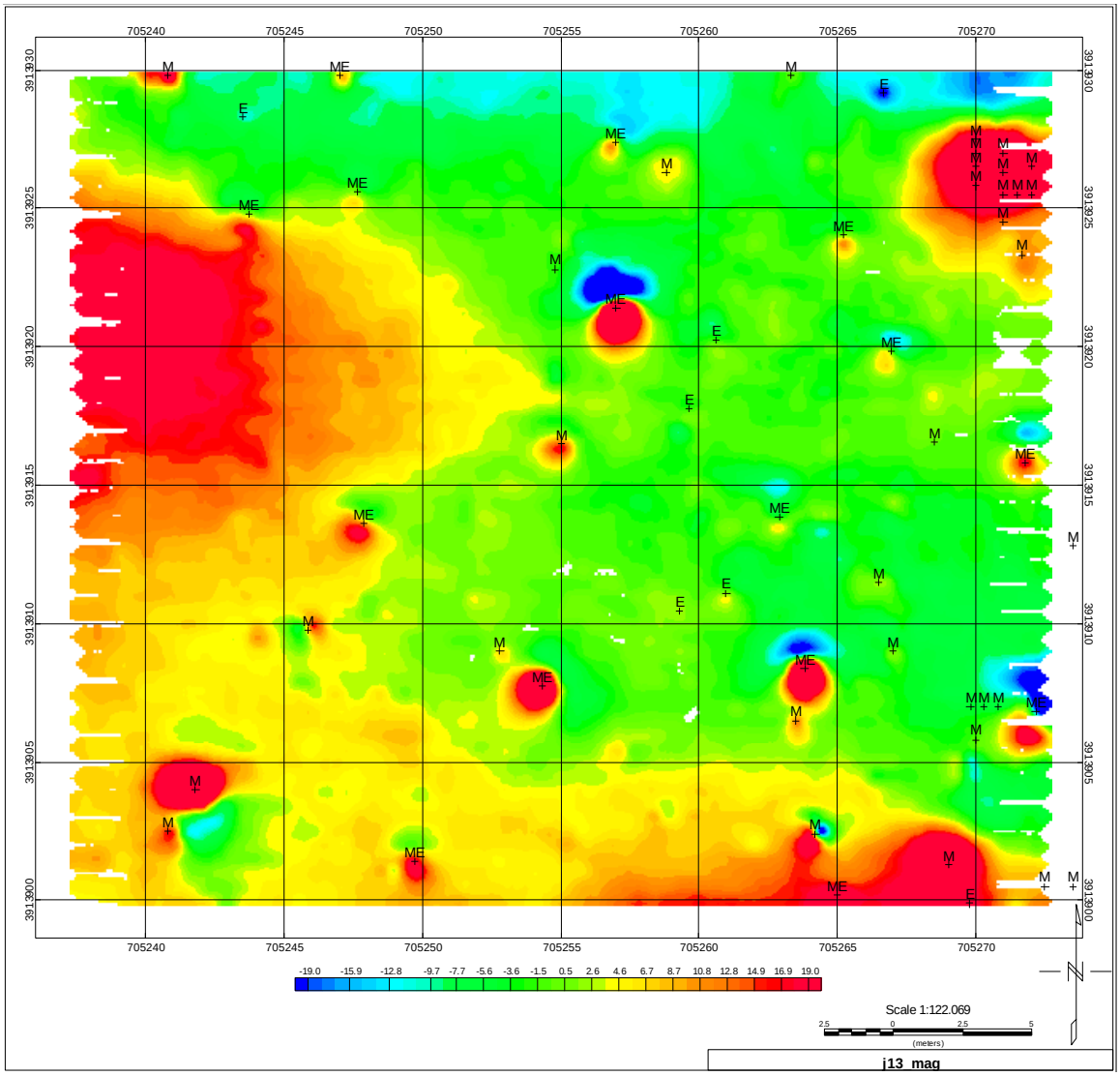
(meters)
j13_em_gate2_leveled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3913900
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:122.069
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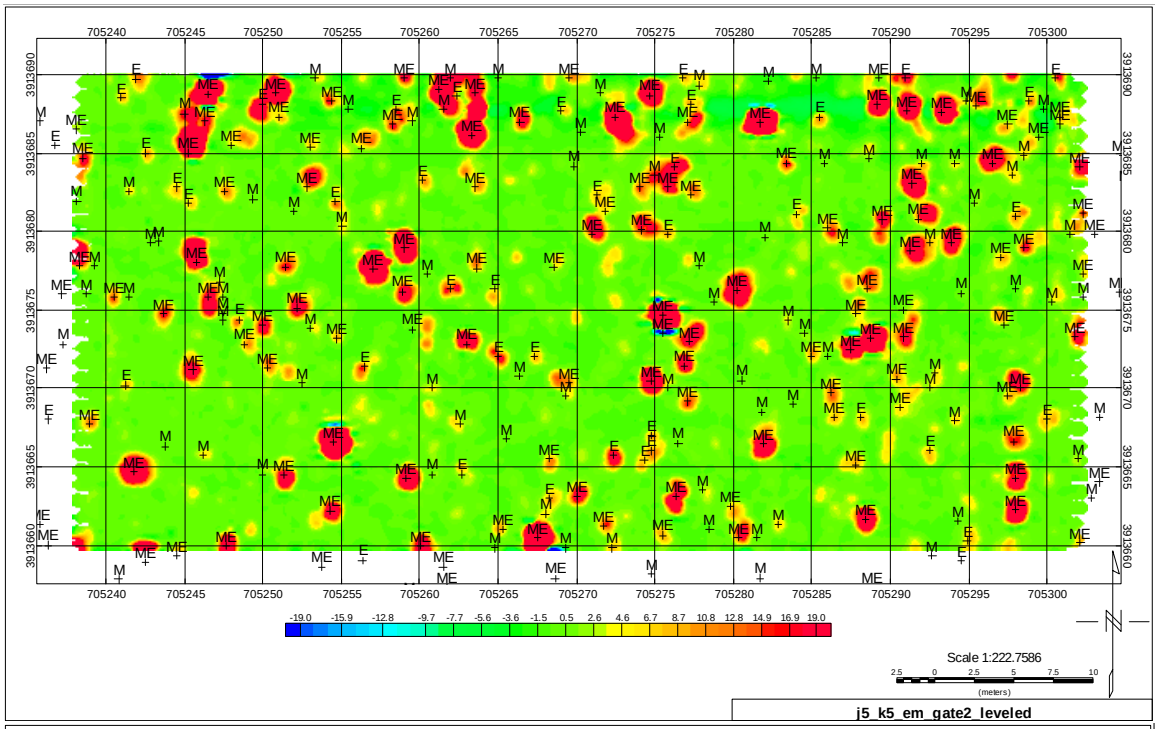
(meters)
j13_mag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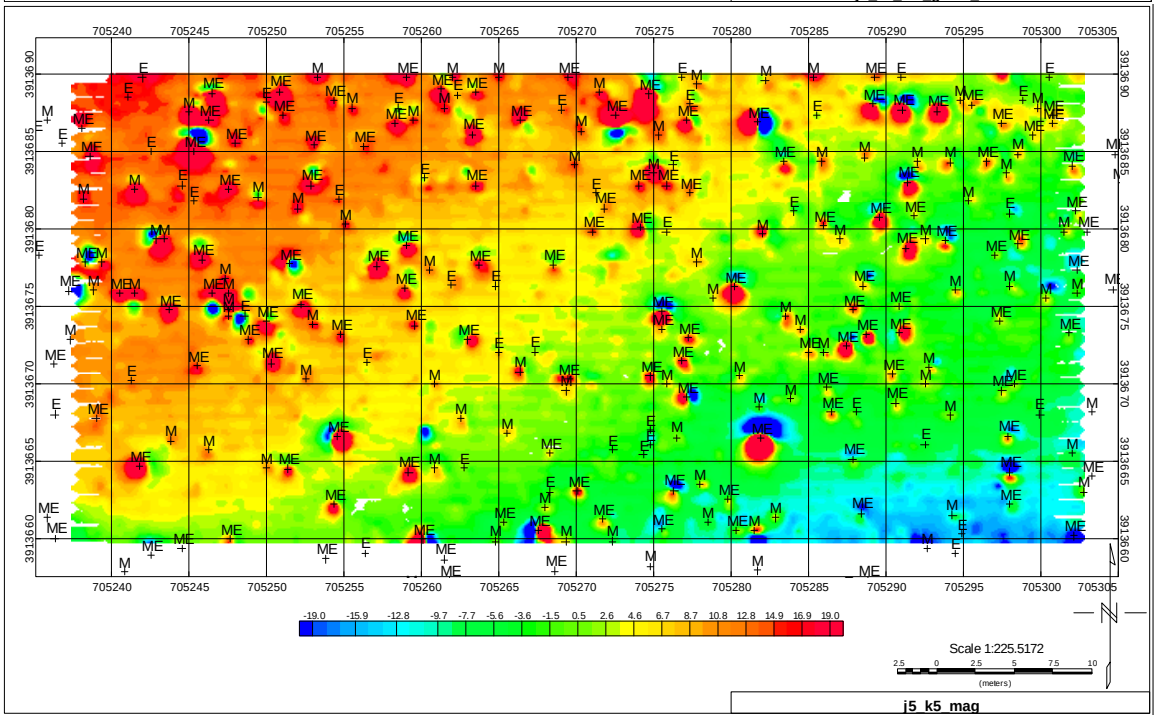
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:222.7586
2.5 0 2.5 5 7.5 10
(meters)
j5_k5_em_gate2_leveled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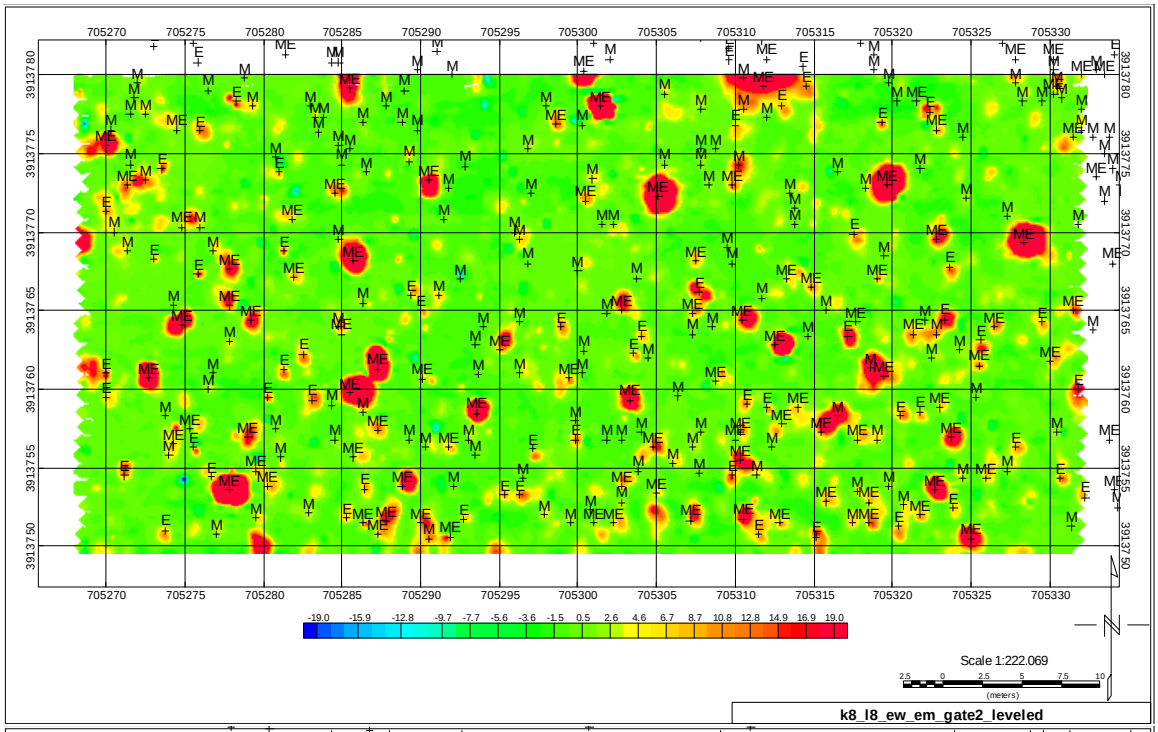
Scale 1:225.5172
2.5 0 2.5 5 7.5 10
(meters)
j5_k5_mag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Scale 1:222.069
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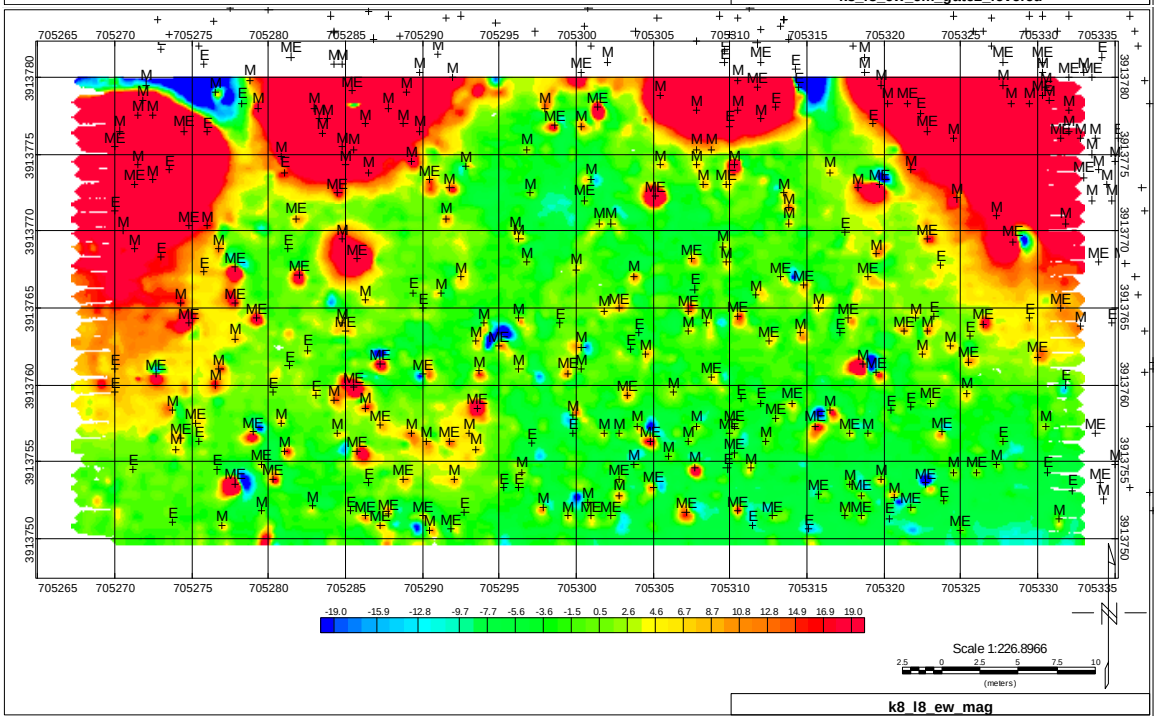
(meters)
k8_l8_ew_em_gate2_leveled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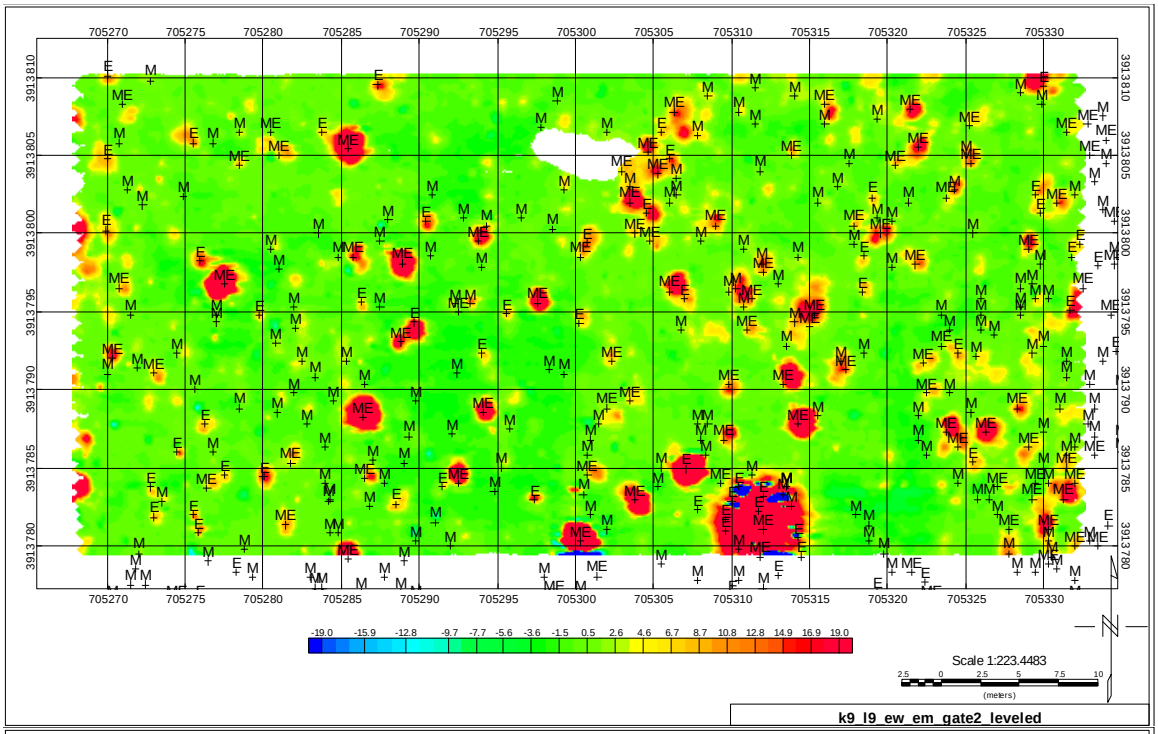
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:226.8966
2.5 0 2.5 5 7.5 10
(meters)
k8_l8_ew_mag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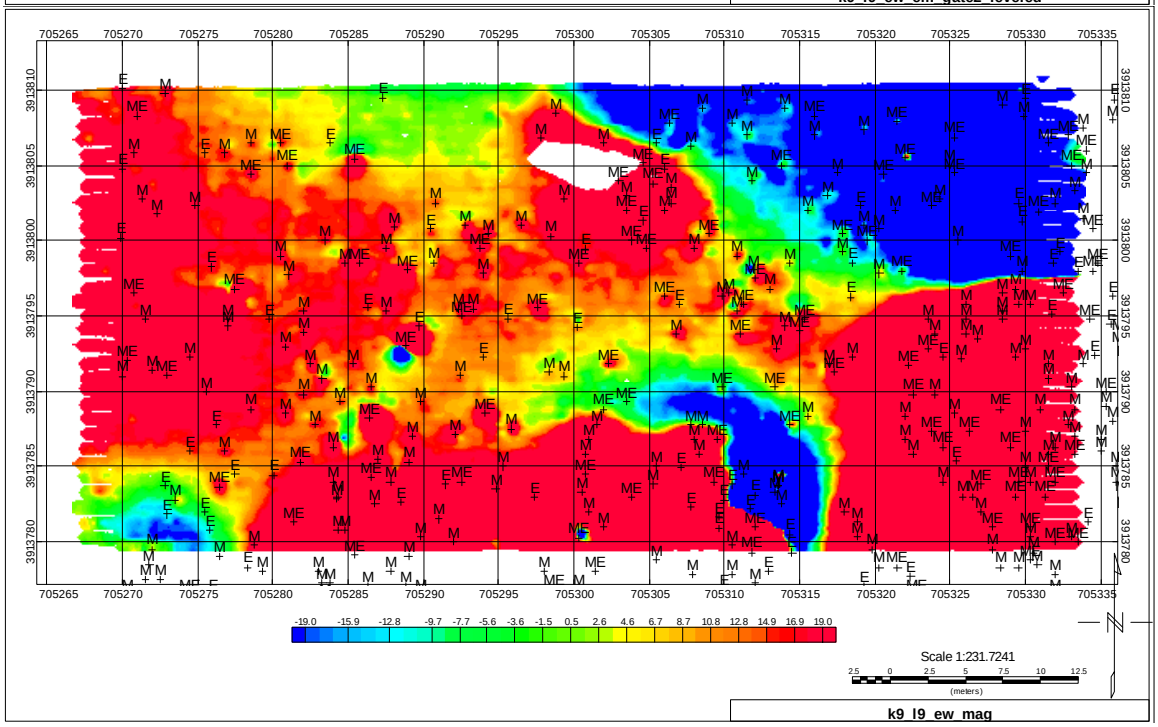
Scale 1:223.4483
2.5 0 2.5 5 7.5 10
(meters)
k9_l9_ew_em_gate2_leveled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Scale 1:231.7241
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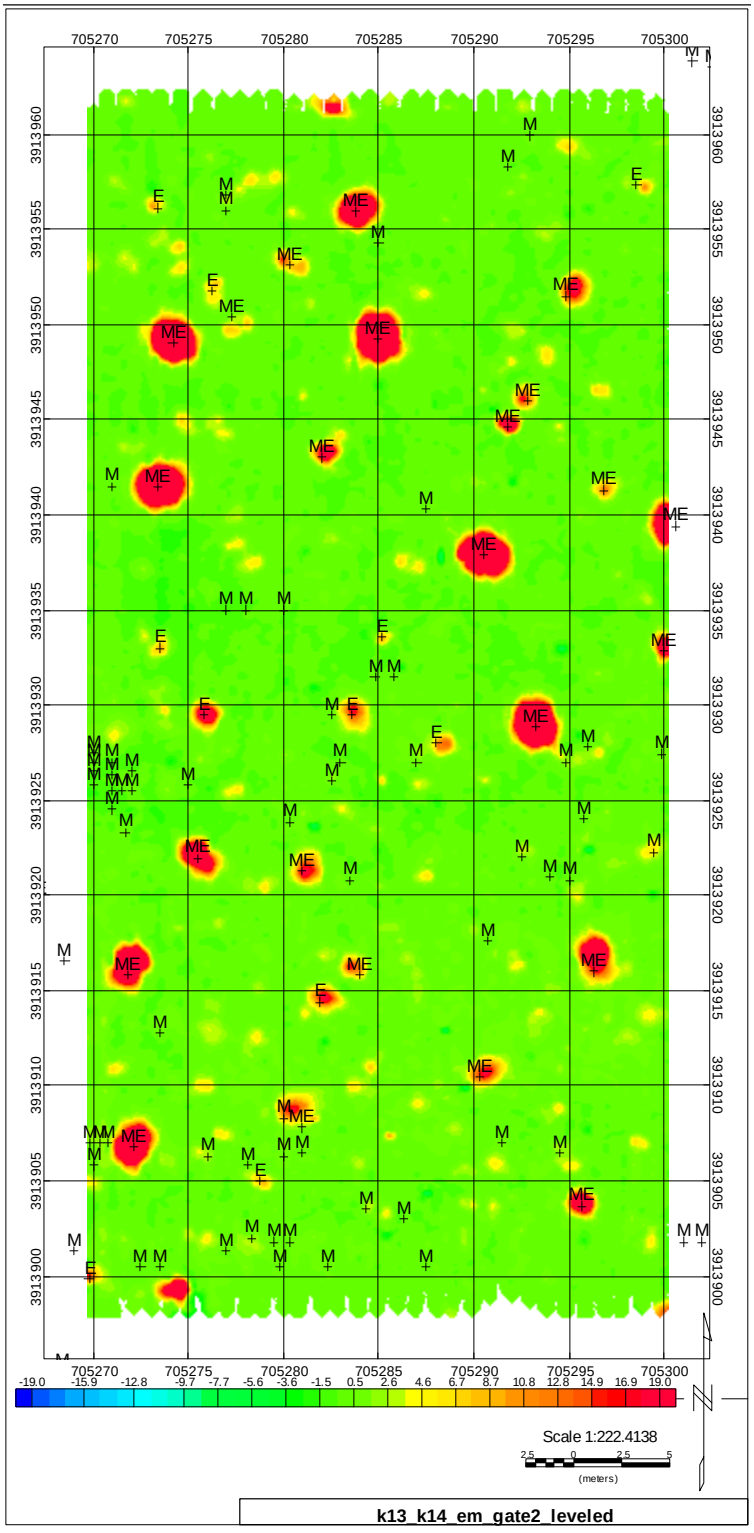
(meters)
k9_l9_ew_mag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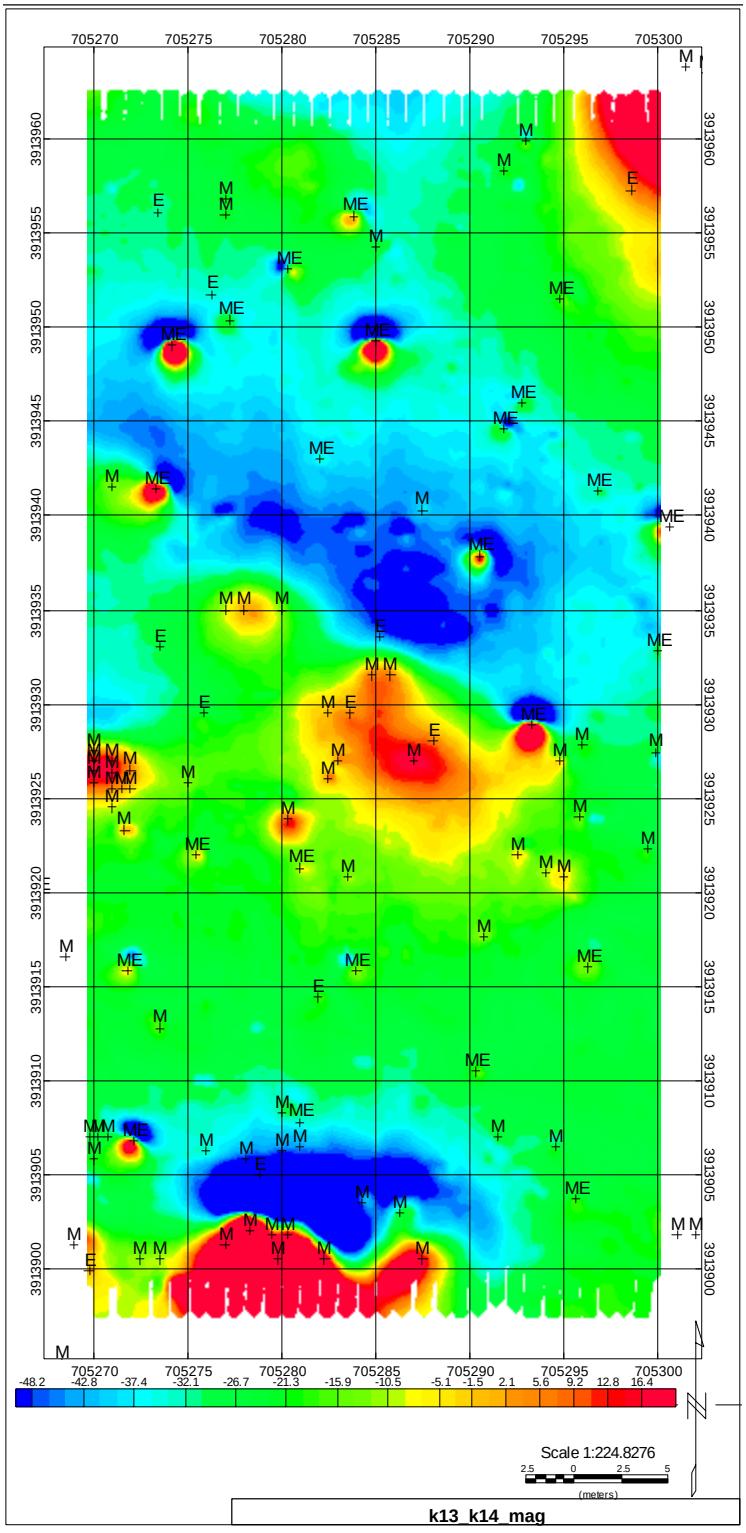
3913910
3913905
3913900
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:222.4138
2.5 0 2.5 5
(meters)
k13_k14_em_gate2_leveled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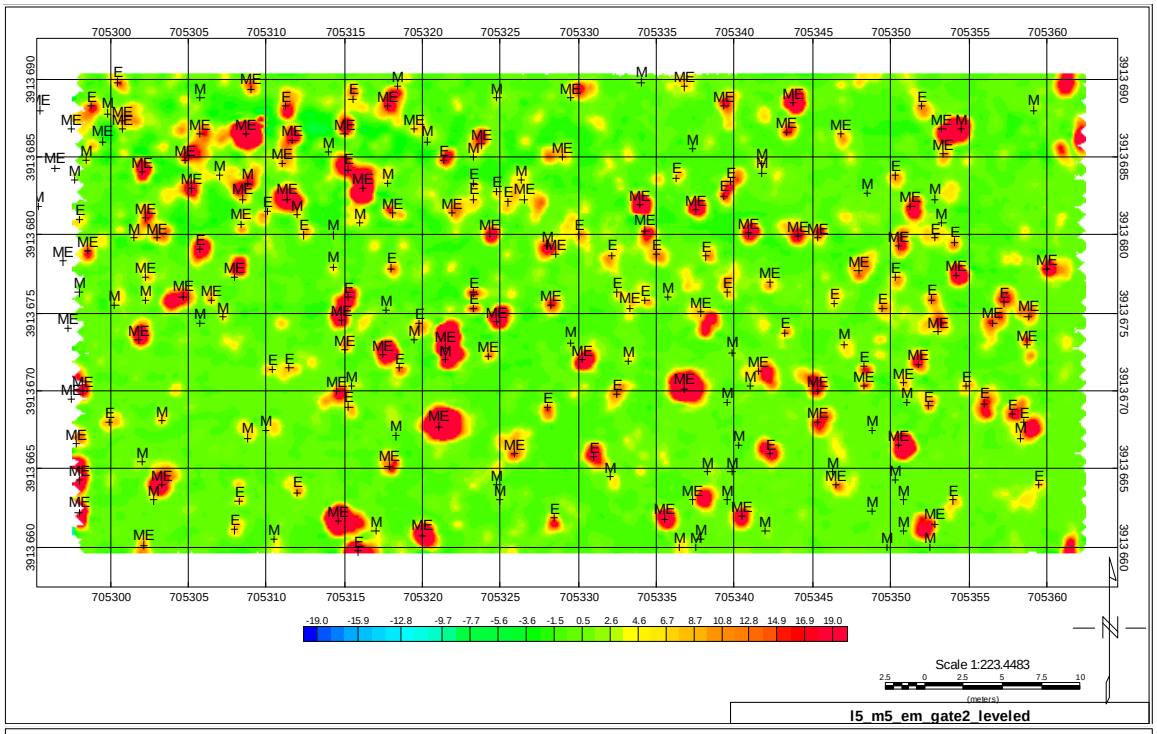
-32.1
-26.7
-21.3
-15.9
-10.5
-5.1
-1.5
2.1
5.6
9.2
12.8
16.4
Scale 1:224.8276
2.5
0
2.5
5
(meters)
k13_k14_mag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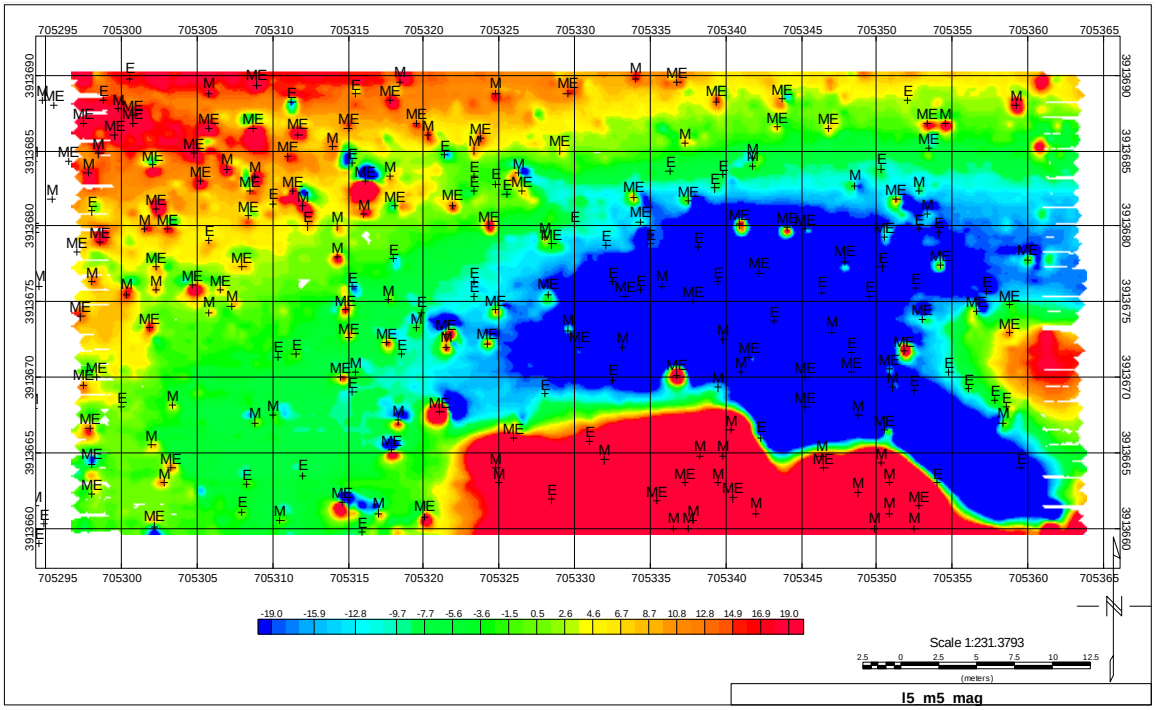
Scale 1:223.4483
2.5 0 2.5 5 7.5 10
(meters)
I5_m5_em_gate2_leveled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Scale 1:231.3793
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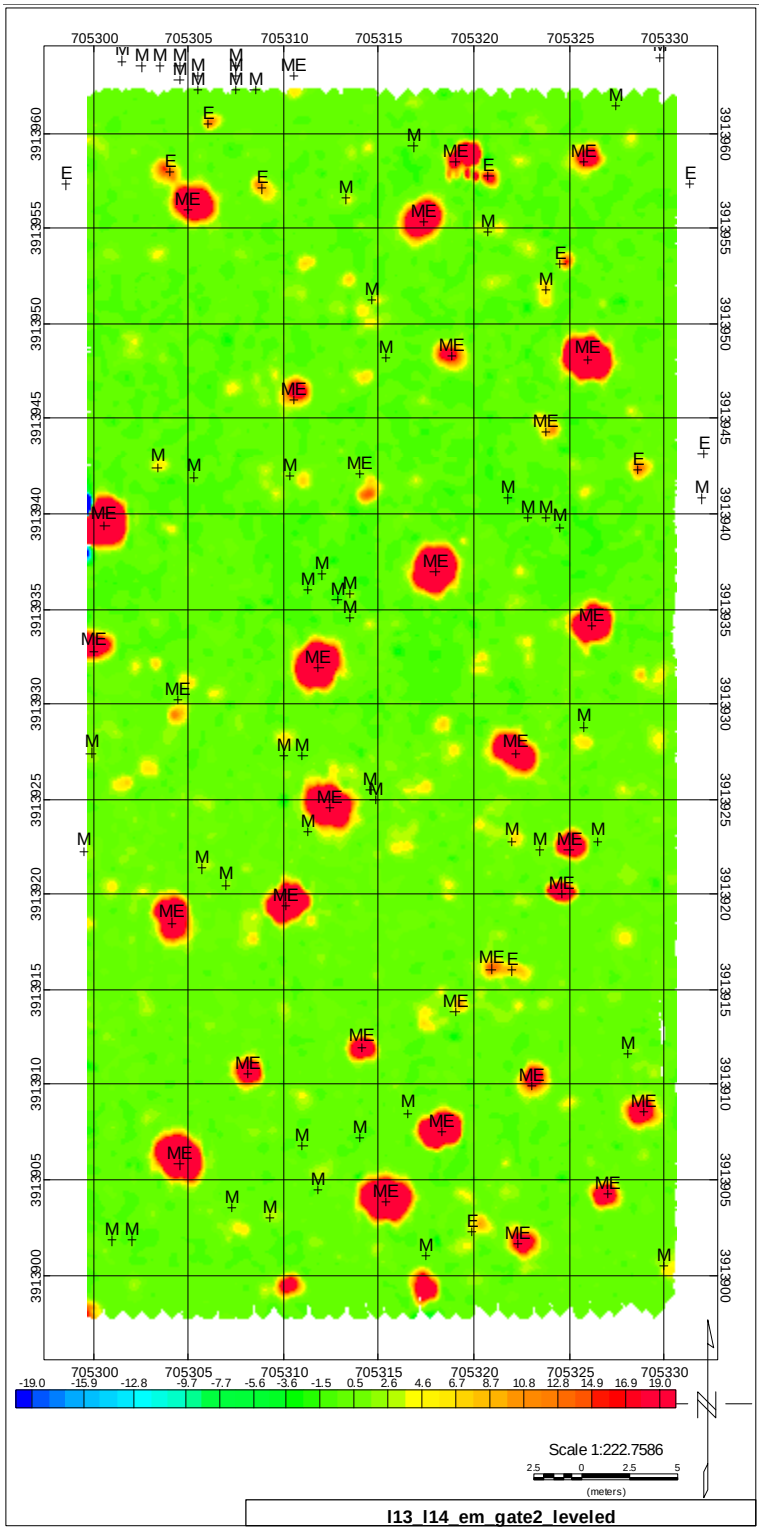
(meters)
I5_m5_mag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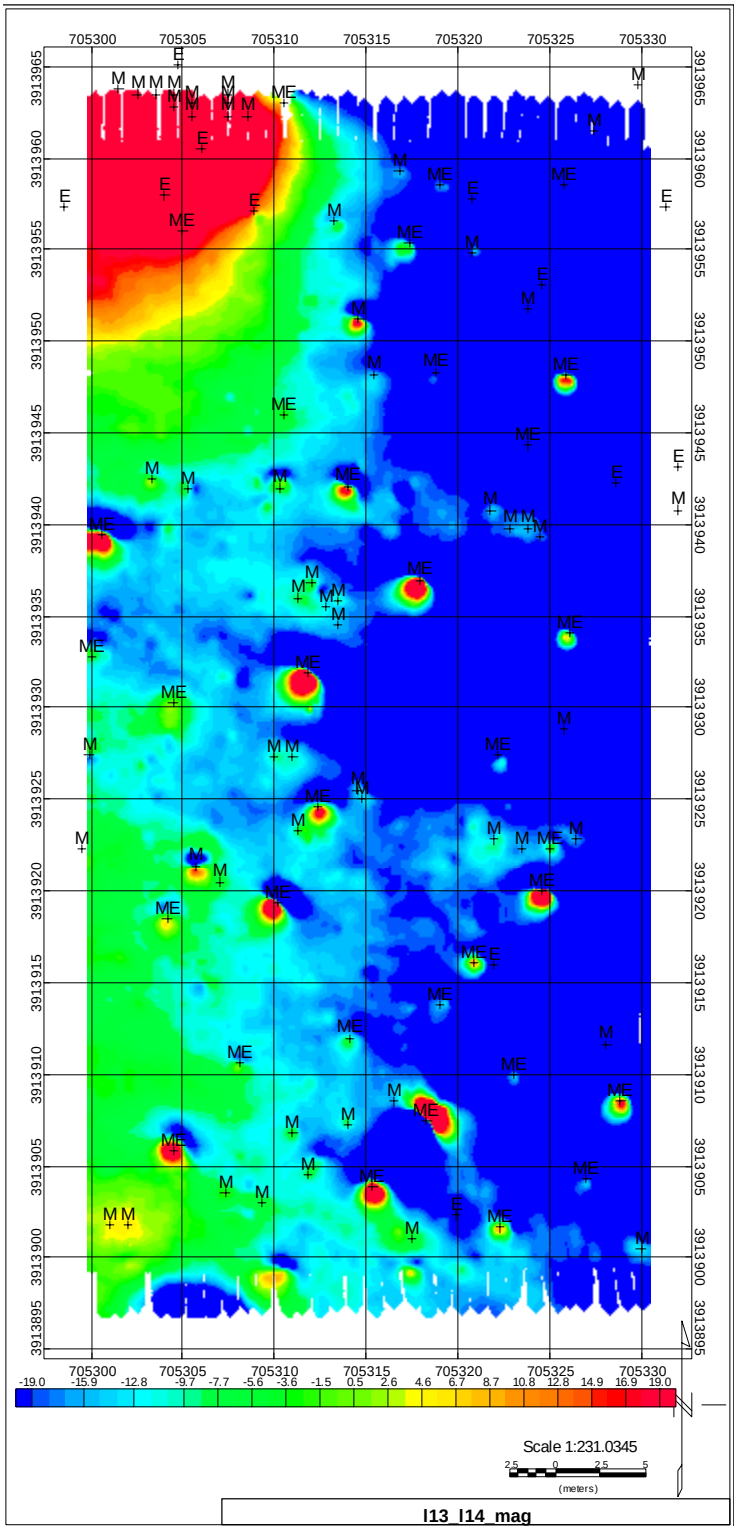
3913925
3913920
3913915
3913910
3913905
3913900
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:222.7586
2.5 0 2.5 5
(meters)
l13_l14_em_gate2_leveled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3913895
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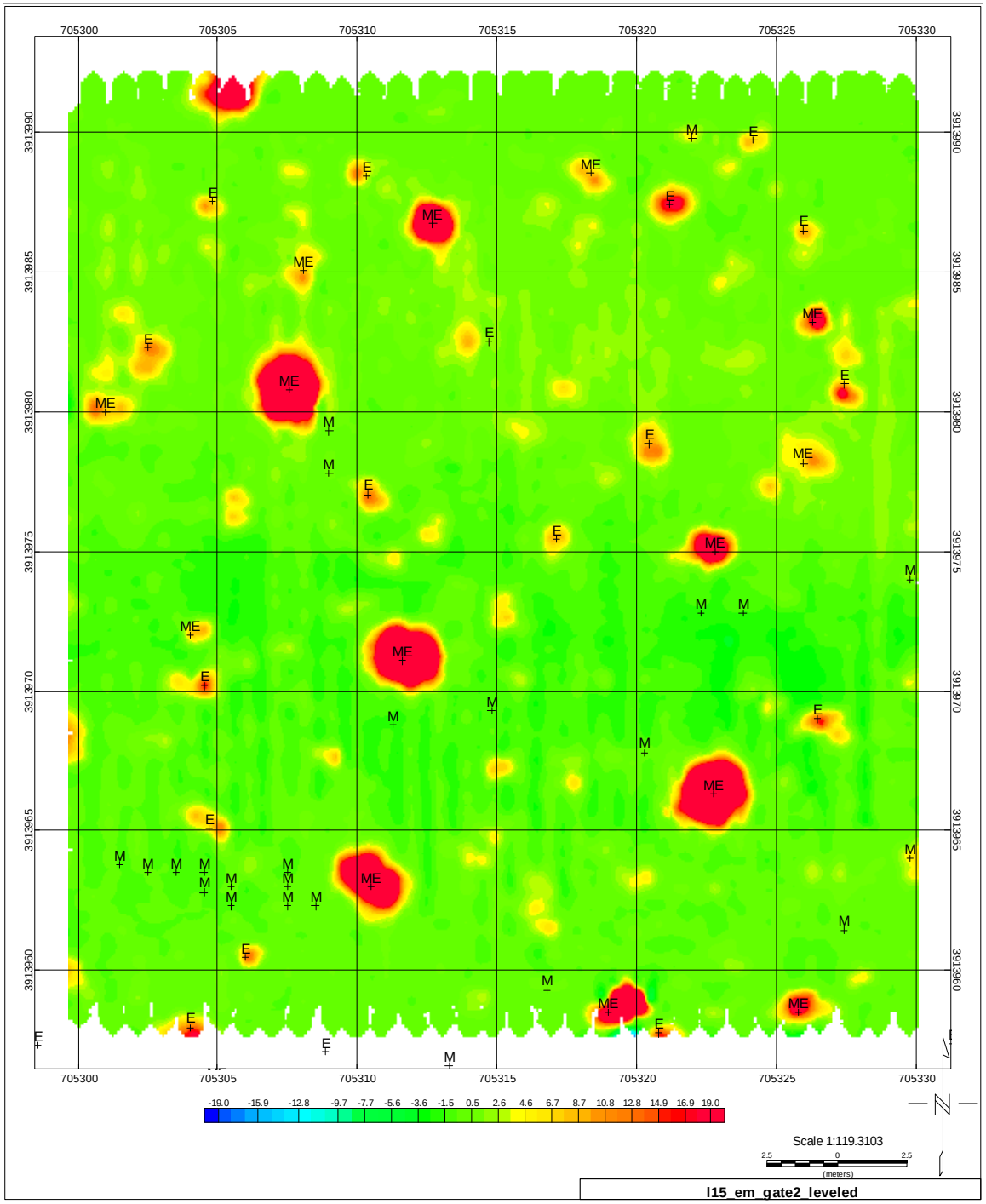
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:231.0345
2.5
0
2.5
5
(meters)
I13_I14_mag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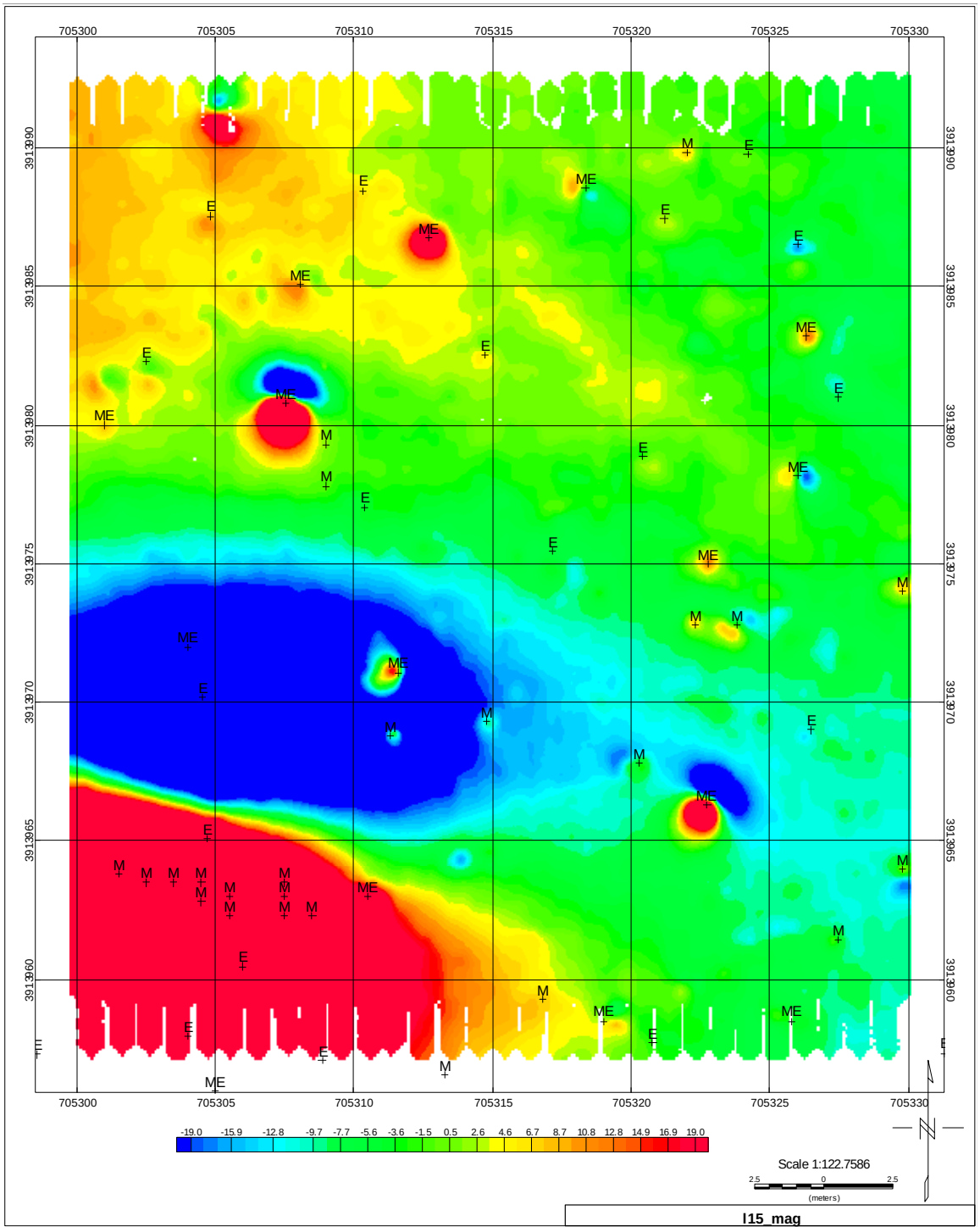
Scale 1:119.3103
2.5 0 2.5
(meters)
I15_em_gate2_leveled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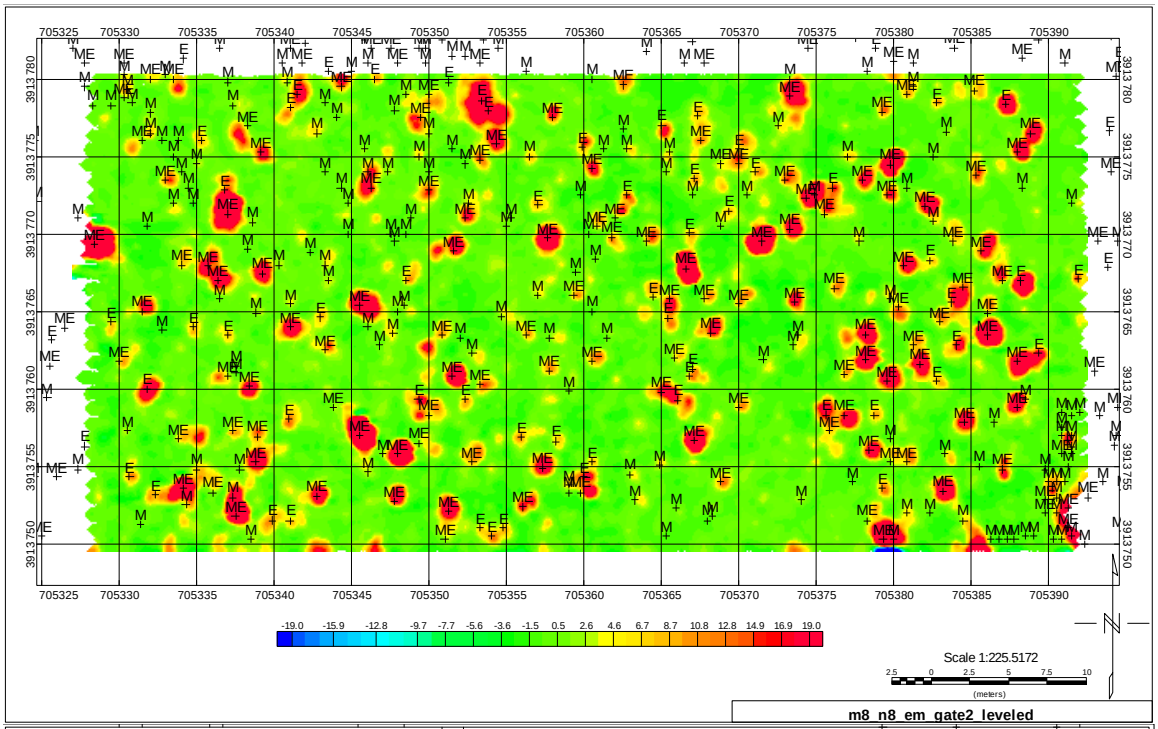
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:122.7586
2.5 0 2.5
(meters)
I15_mag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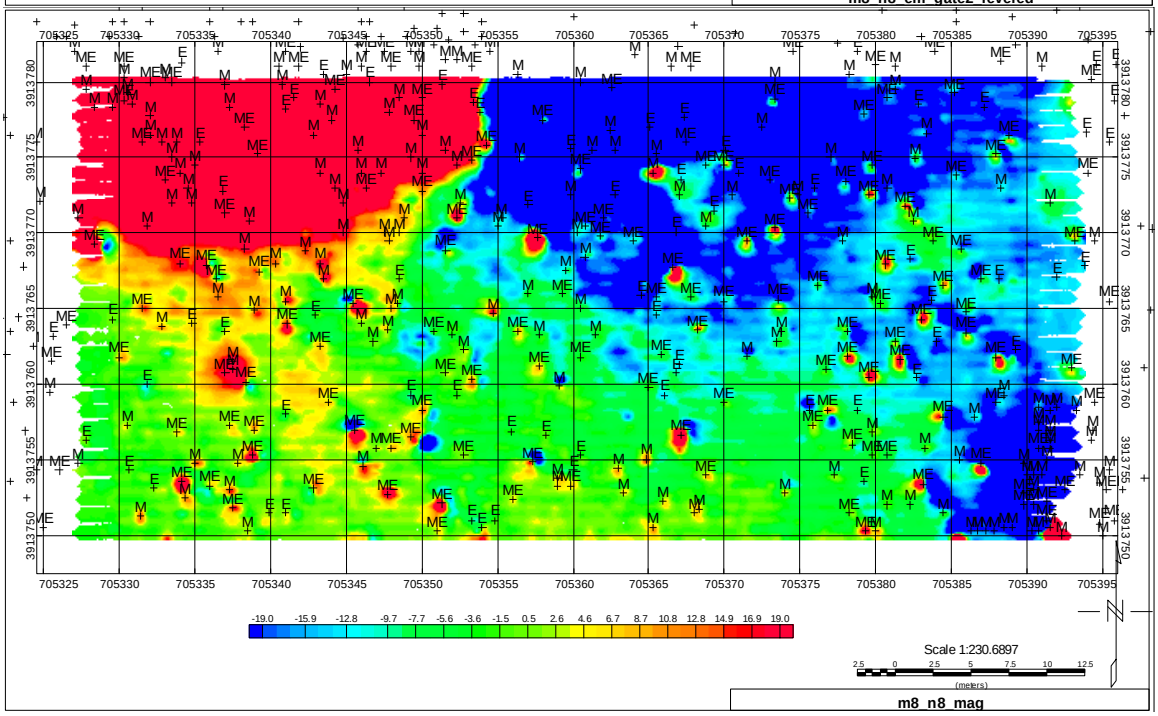
Scale 1:225.5172
2.5 0 2.5 5 7.5 10
(meters)
m8_n8_em_gate2_leveled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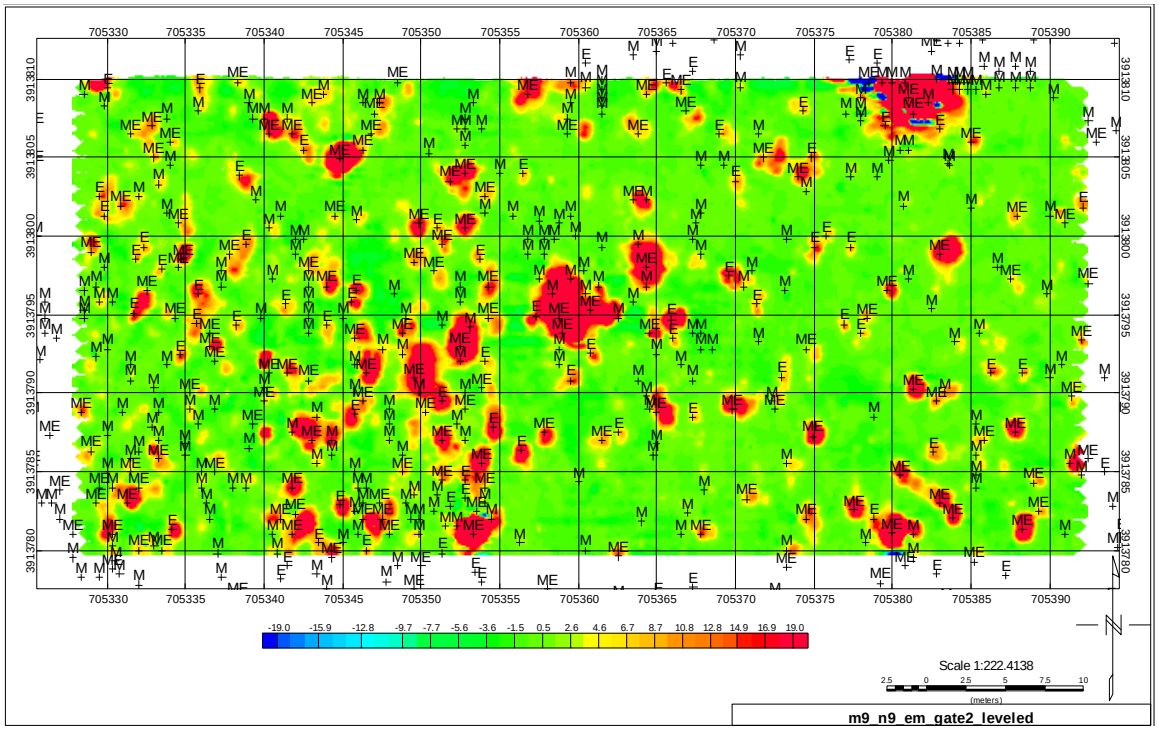
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:230.6897
2.5 0 2.5 5 7.5 10 12.5
(meters)
m8_n8_mag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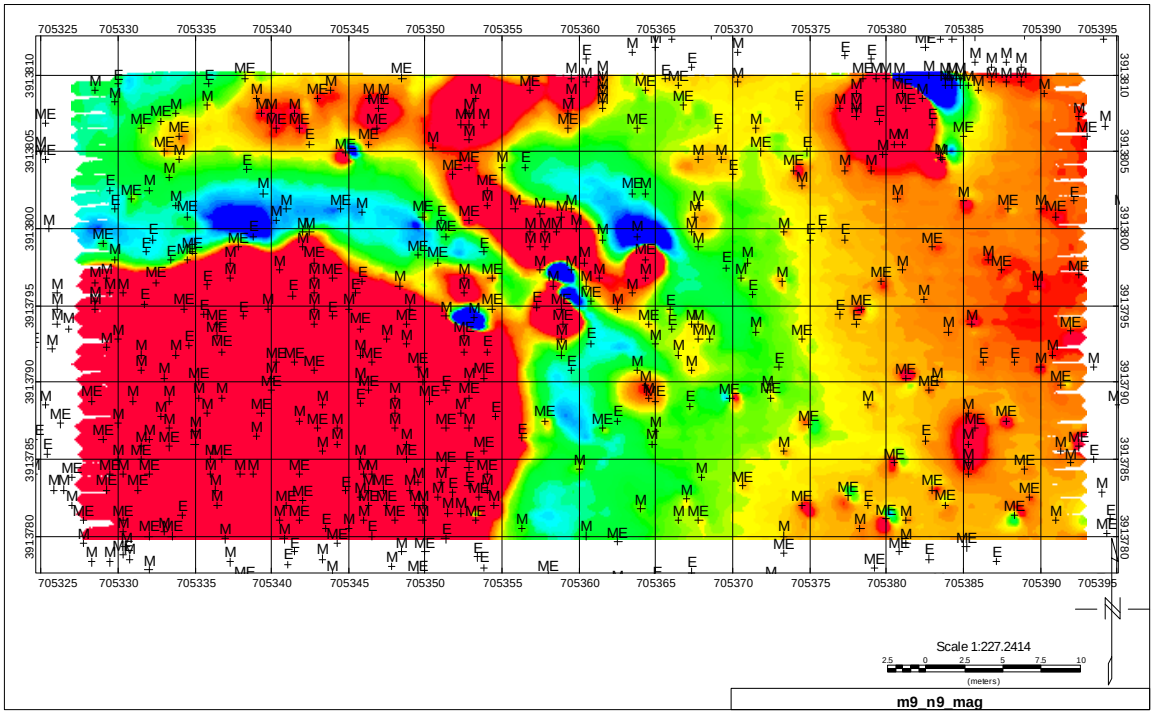
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:222.4138
2.5 0 2.5 5 7.5 10
(meters)
m9_n9_em_gate2_leveled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Scale 1:227.2414
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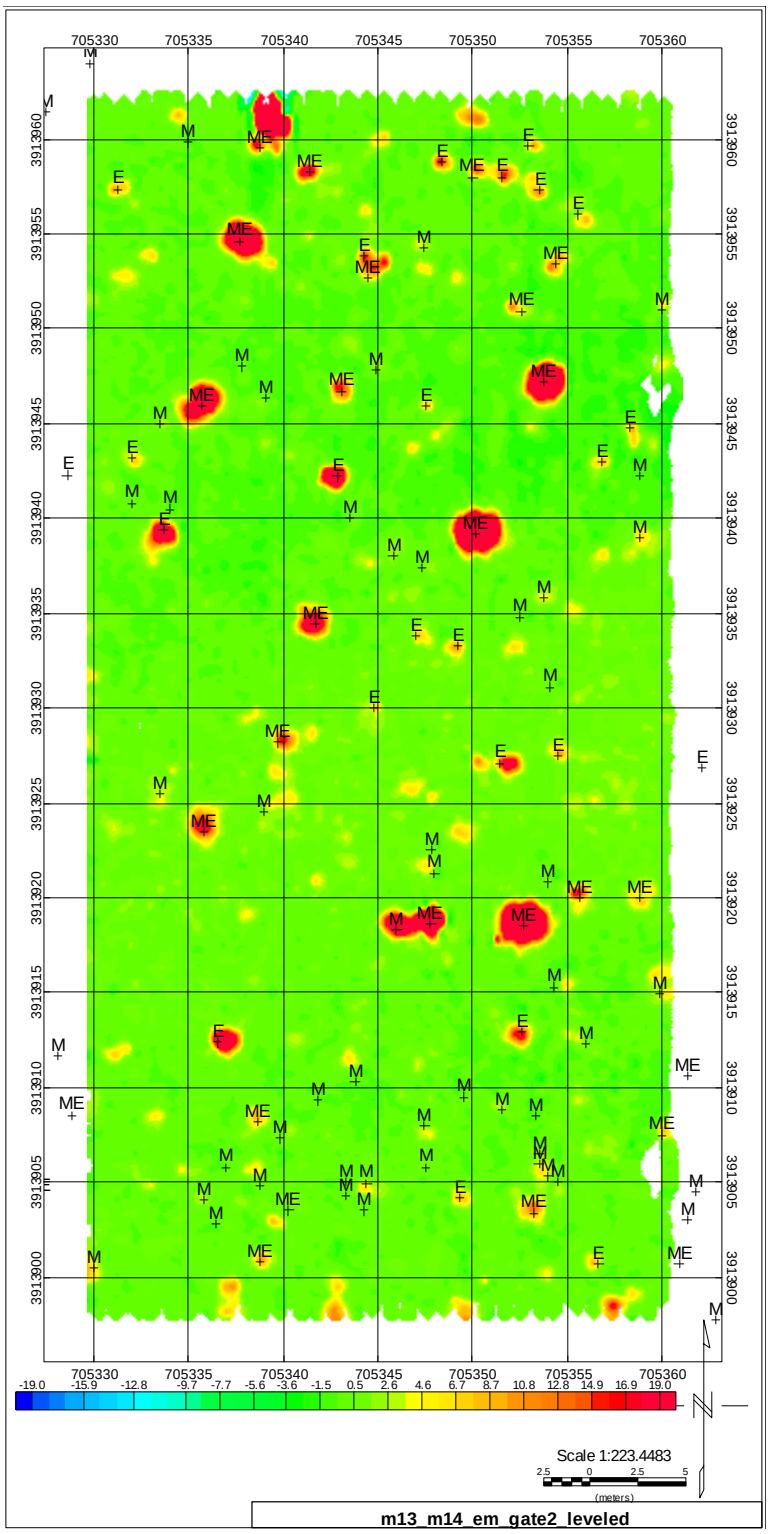
(meters)
m9_n9_mag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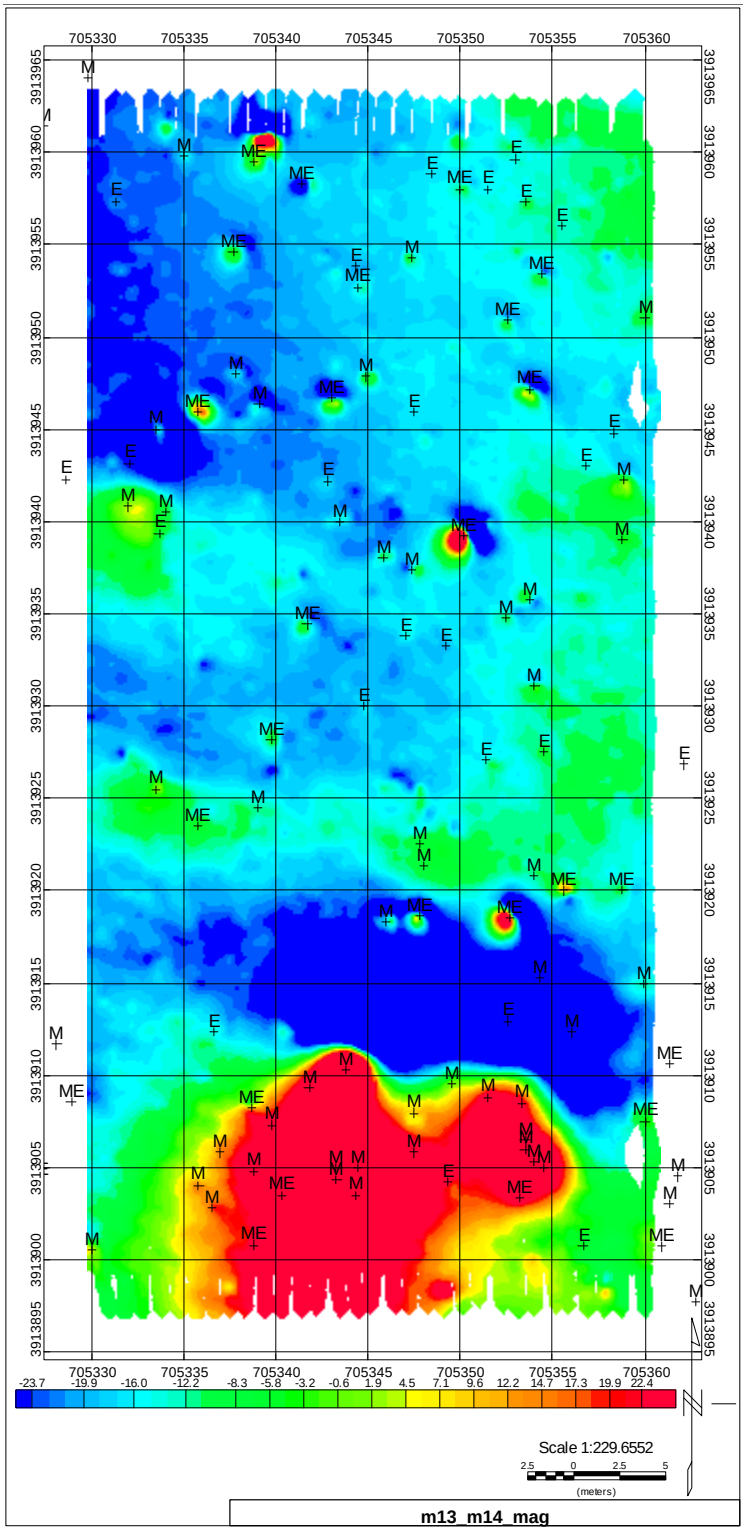
Scale 1:223.4483
2.5 0 2.5 5
(meters)
m13_m14_em_gate2_leveled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3913900
3913895
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Scale 1:229.6552
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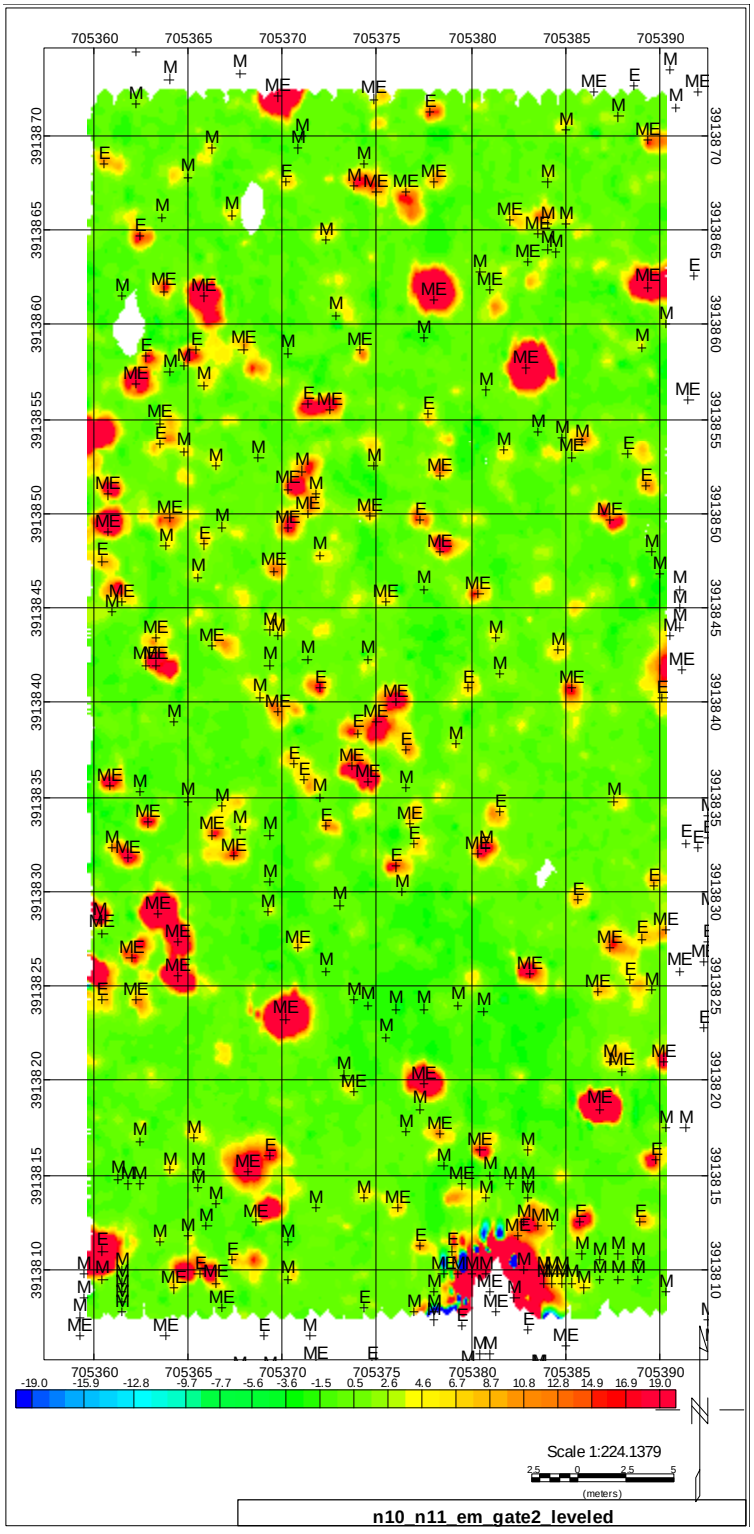
(meters)
m13_m14_mag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-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
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16.9
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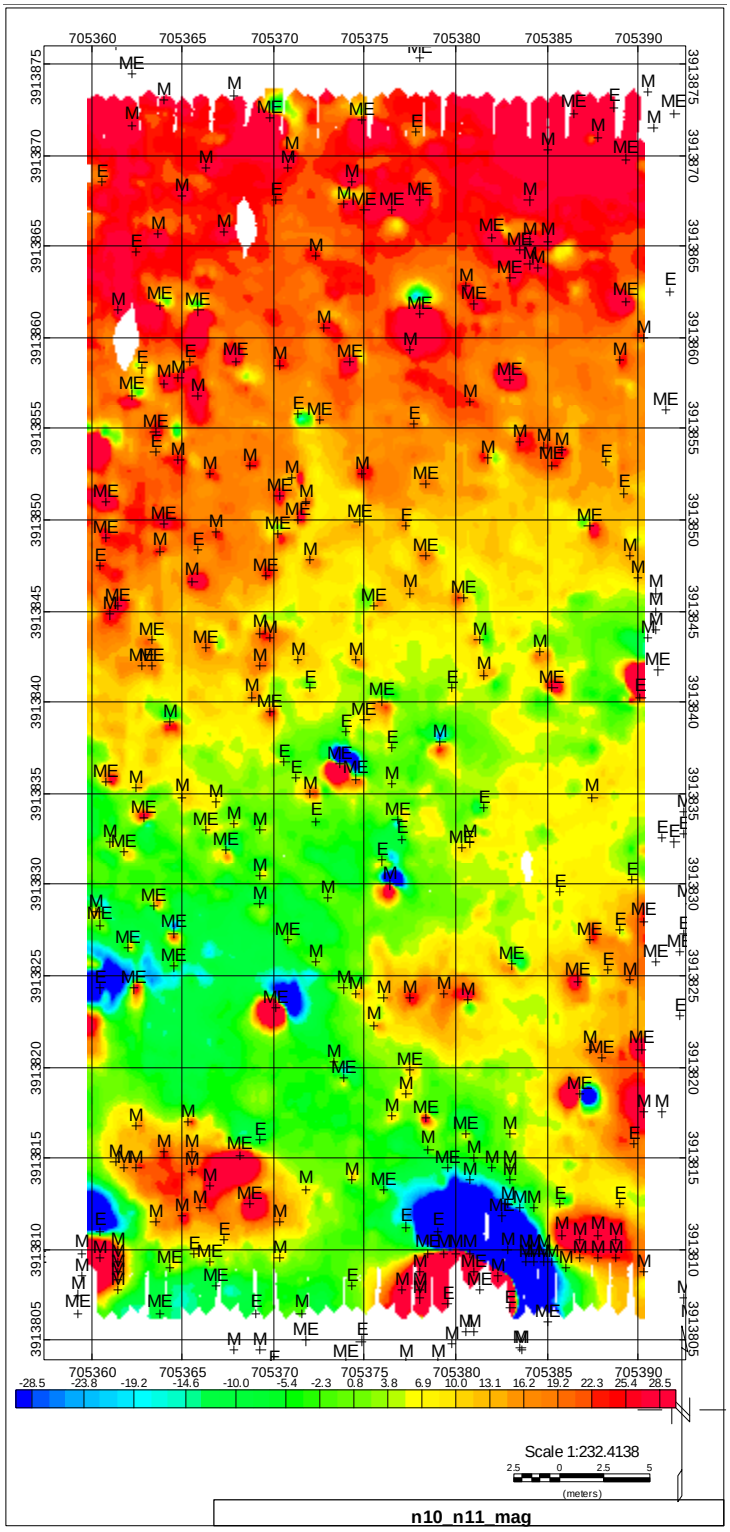
Scale 1:224.1379
2.5
0
2.5
5
(meters)
n10_n11_em_gate2_leveled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3.8
6.9
10.0
13.1
16.2
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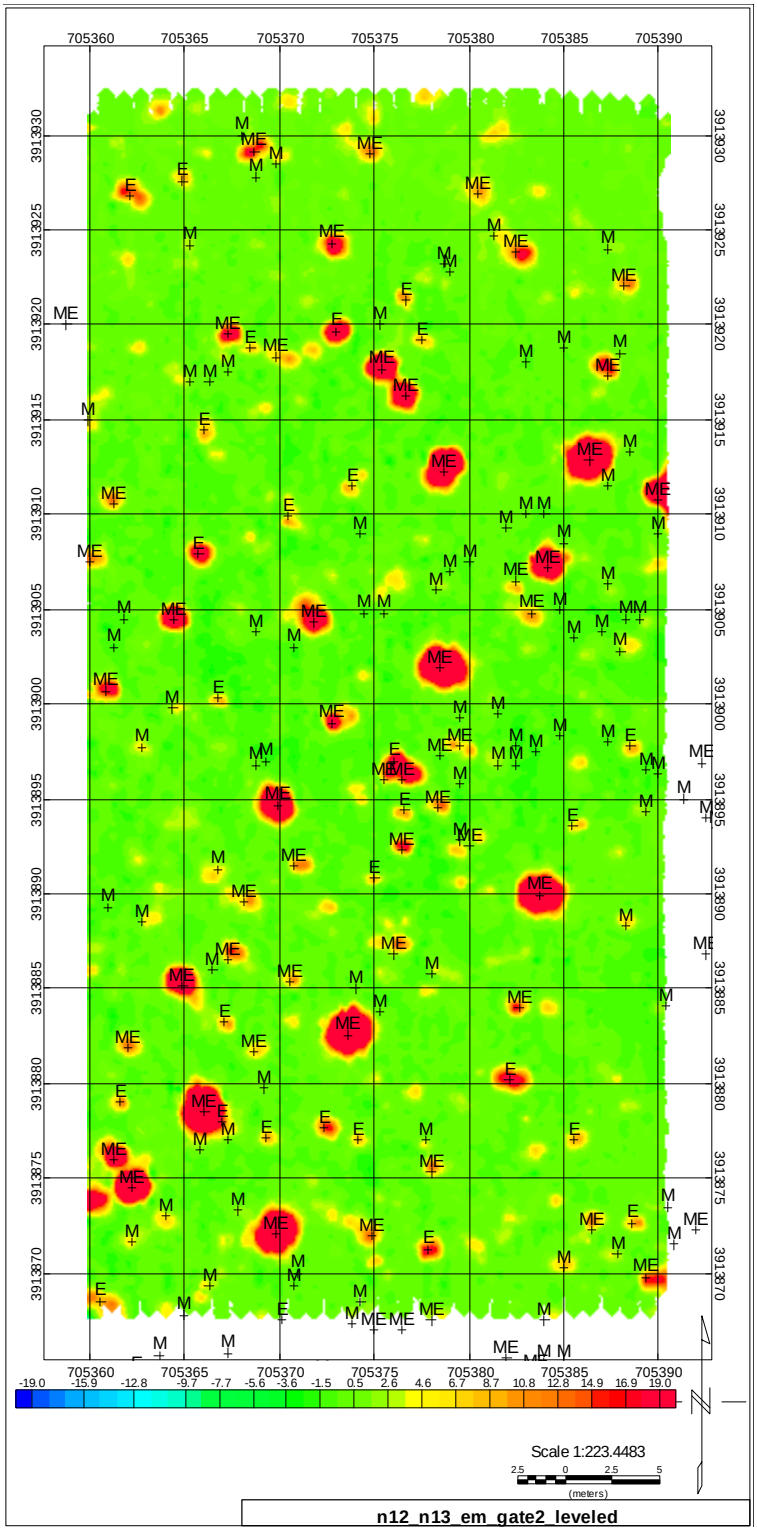
25.4
28.5
Scale 1:232.4138
2.5
0
2.5
5
(meters)
n10_n11_mag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3913890
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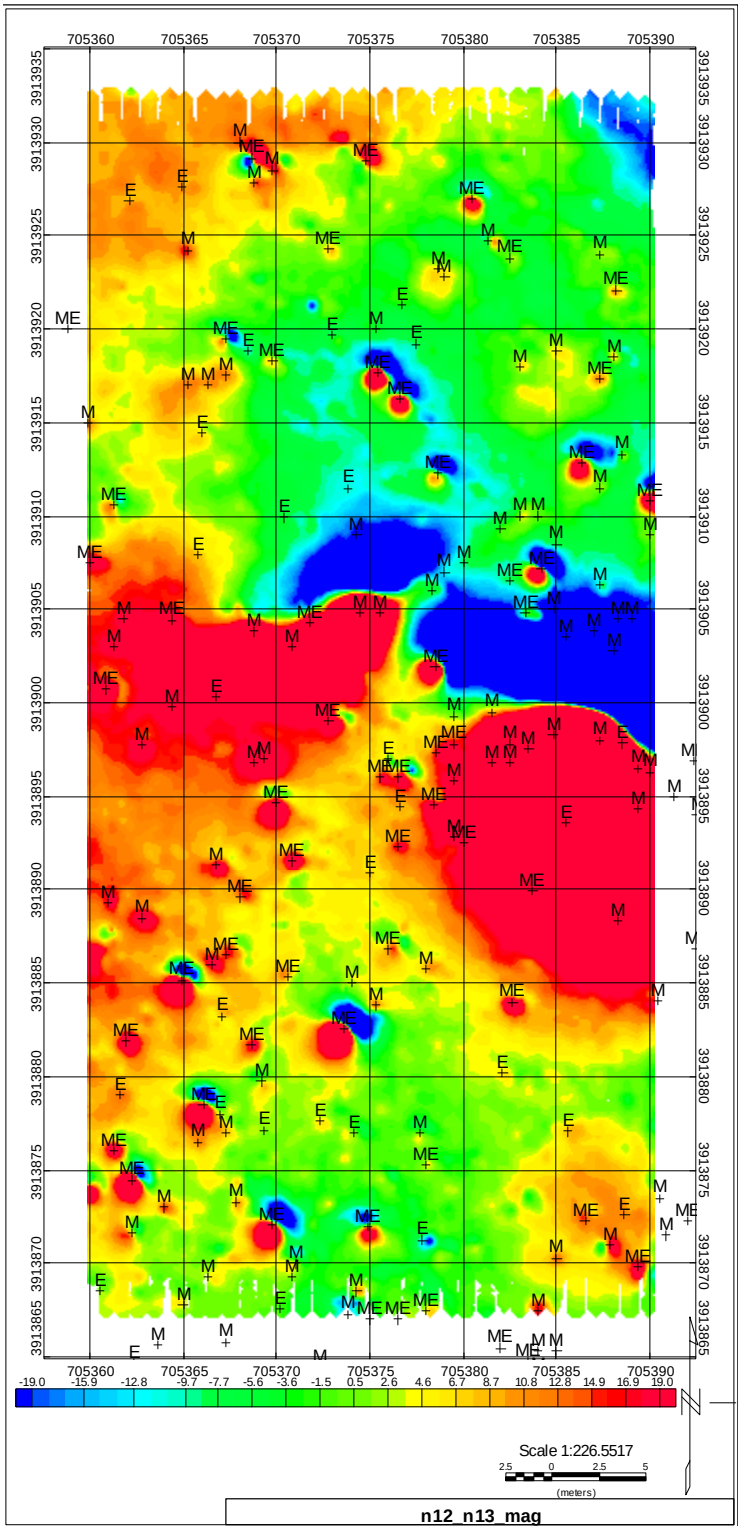
3913880
3913875
3913870
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:223.4483
2.5 0 2.5 5
(meters)
n12_n13_em_gate2_leveled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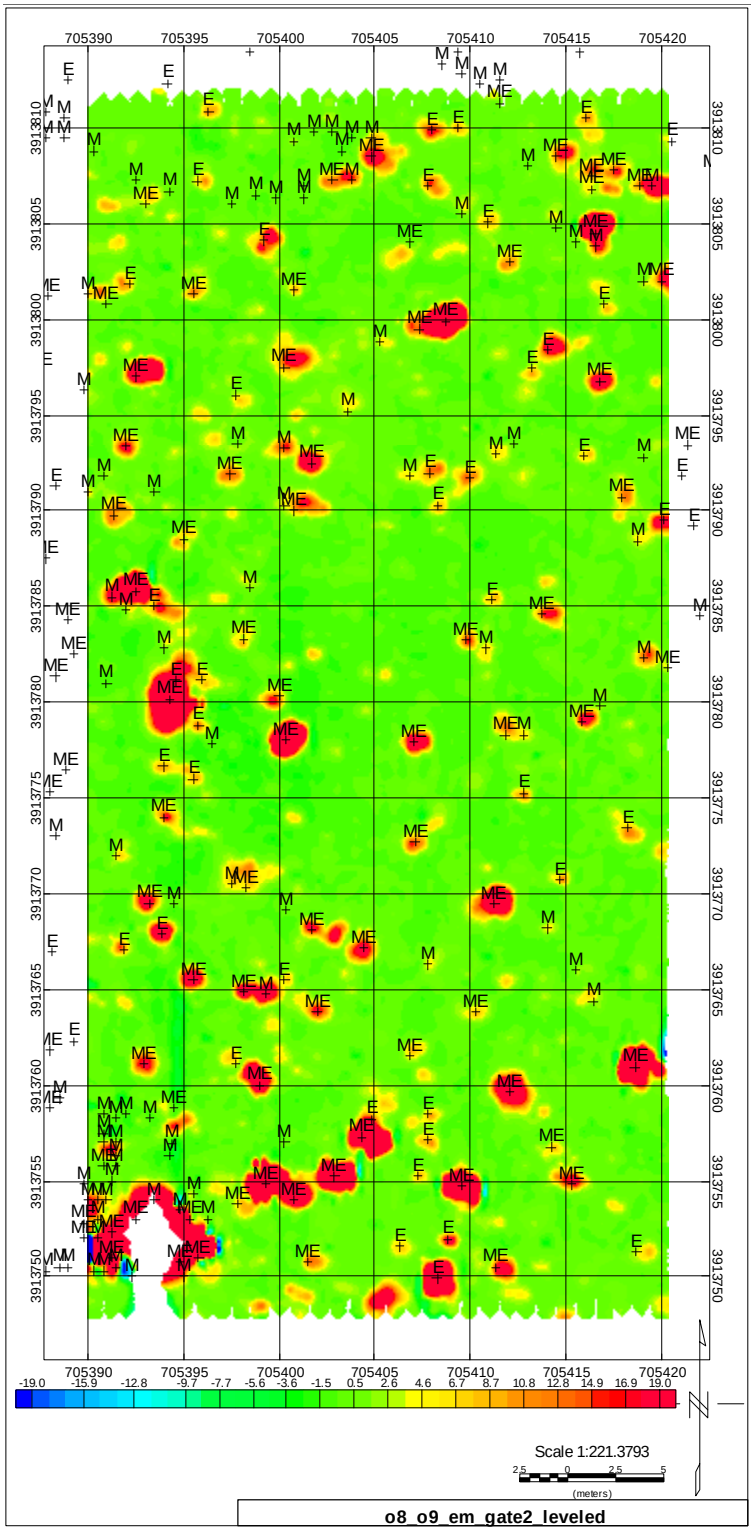
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:226.5517
2.5 0 2.5 5
(meters)
n12_n13_mag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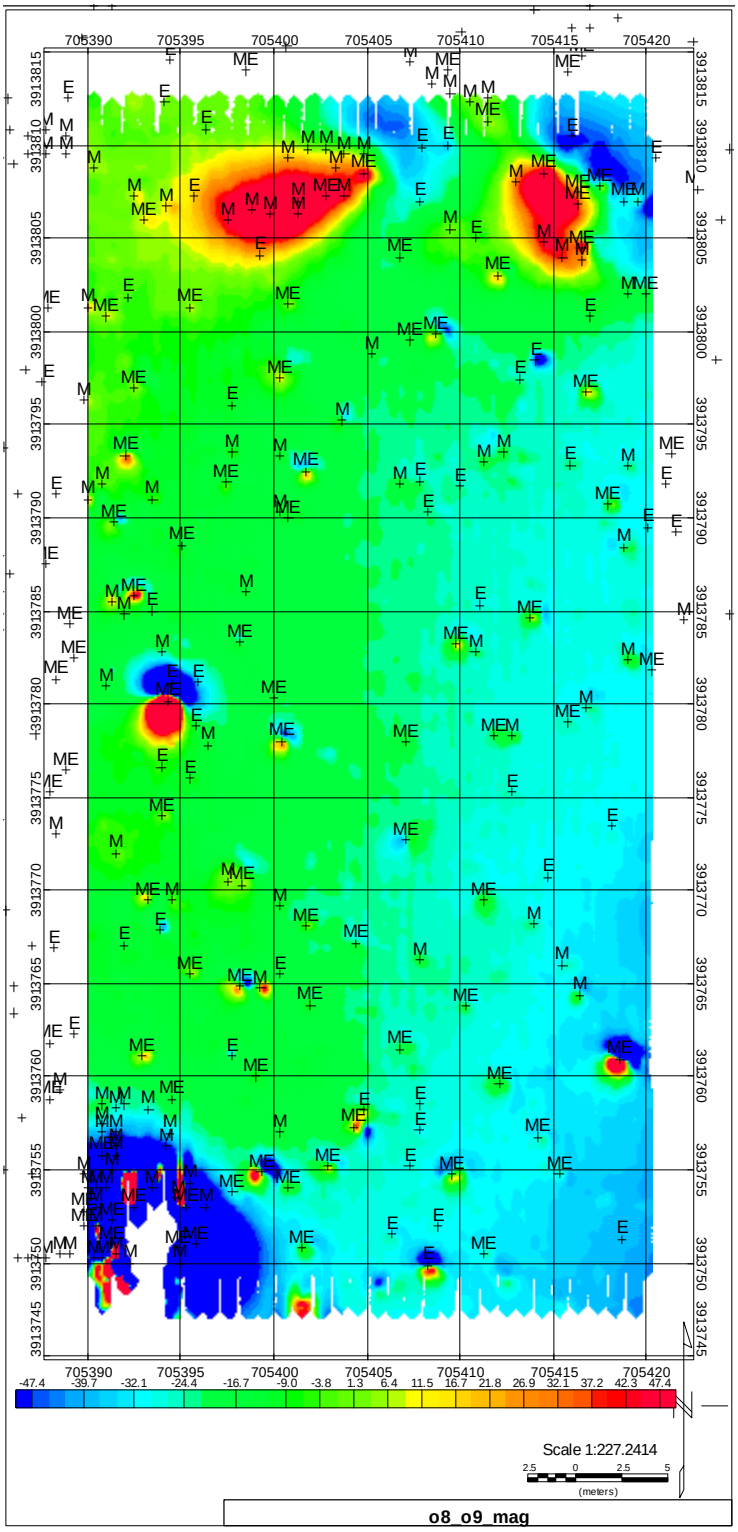
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:221.3793
2.5
0
2.5
5
(meters)
o8_o9_em_gate2_leveled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-39.7
-32.1
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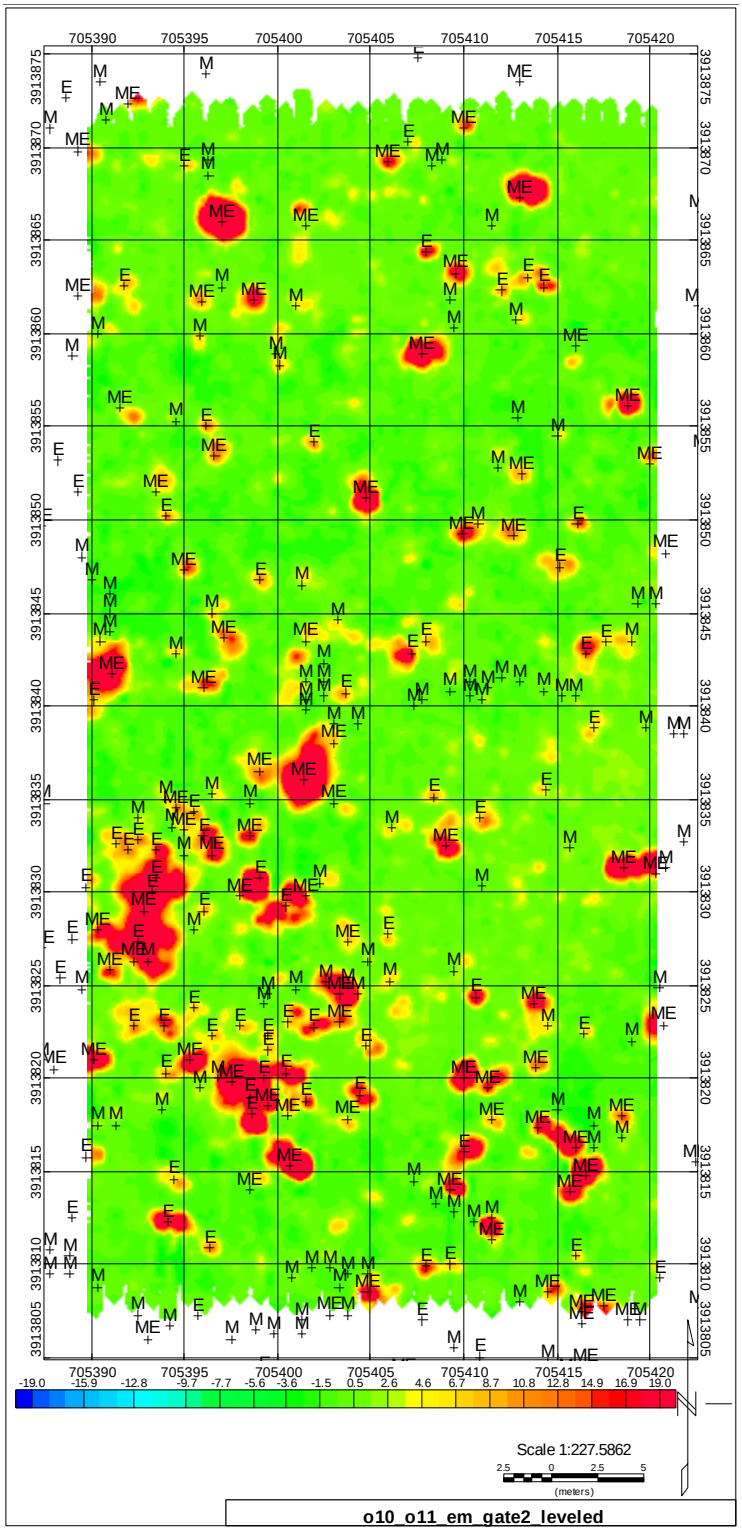
-16.7
-9.0
-3.8
1.3
6.4
11.5
16.7
21.8
26.9
32.1
37.2
42.3
47.4
Scale 1:227.2414
2.5
0
2.5
5
(meters)
o8_o9_mag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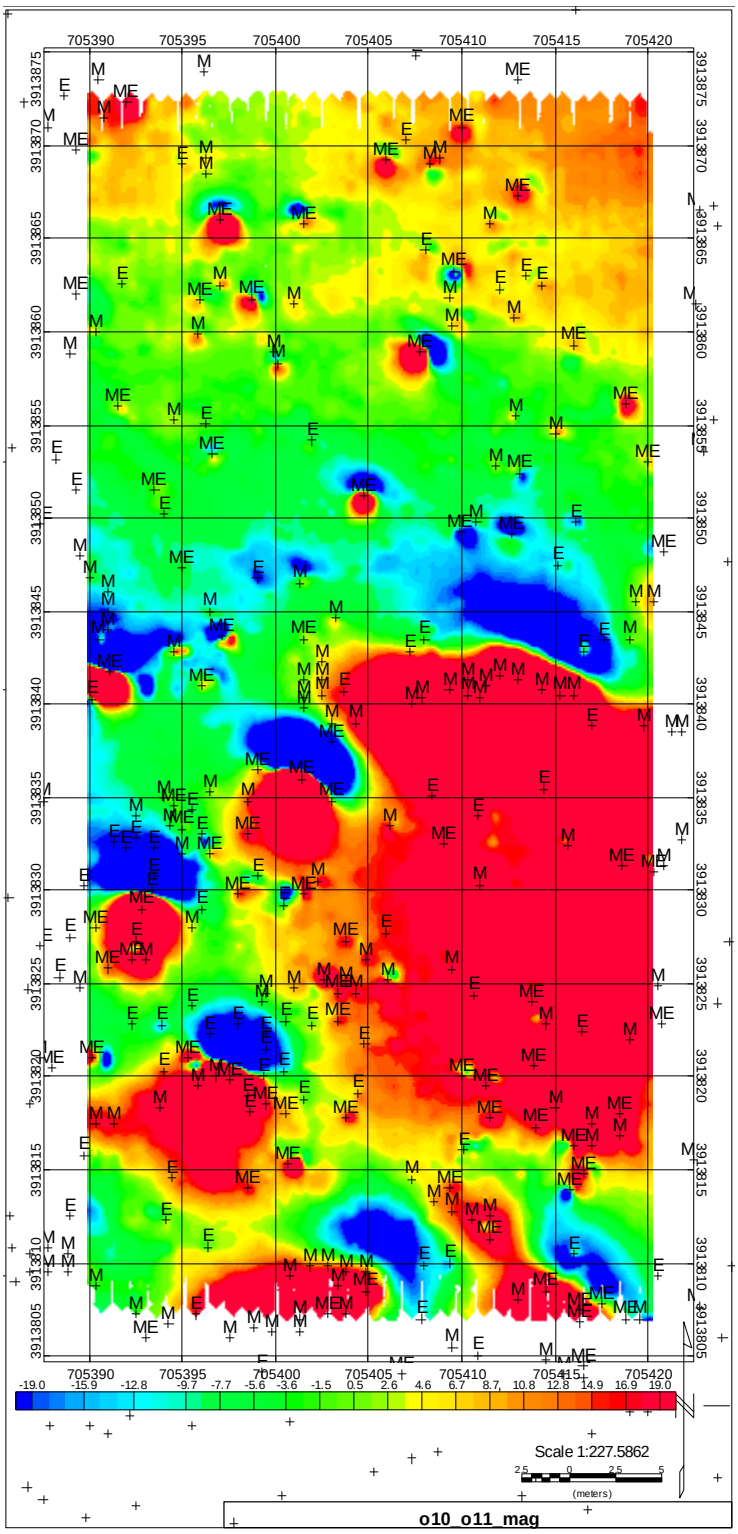
3913805
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:227.5862
2.5
0
2.5
5
(meters)
o10_o11_em_gate2_leveled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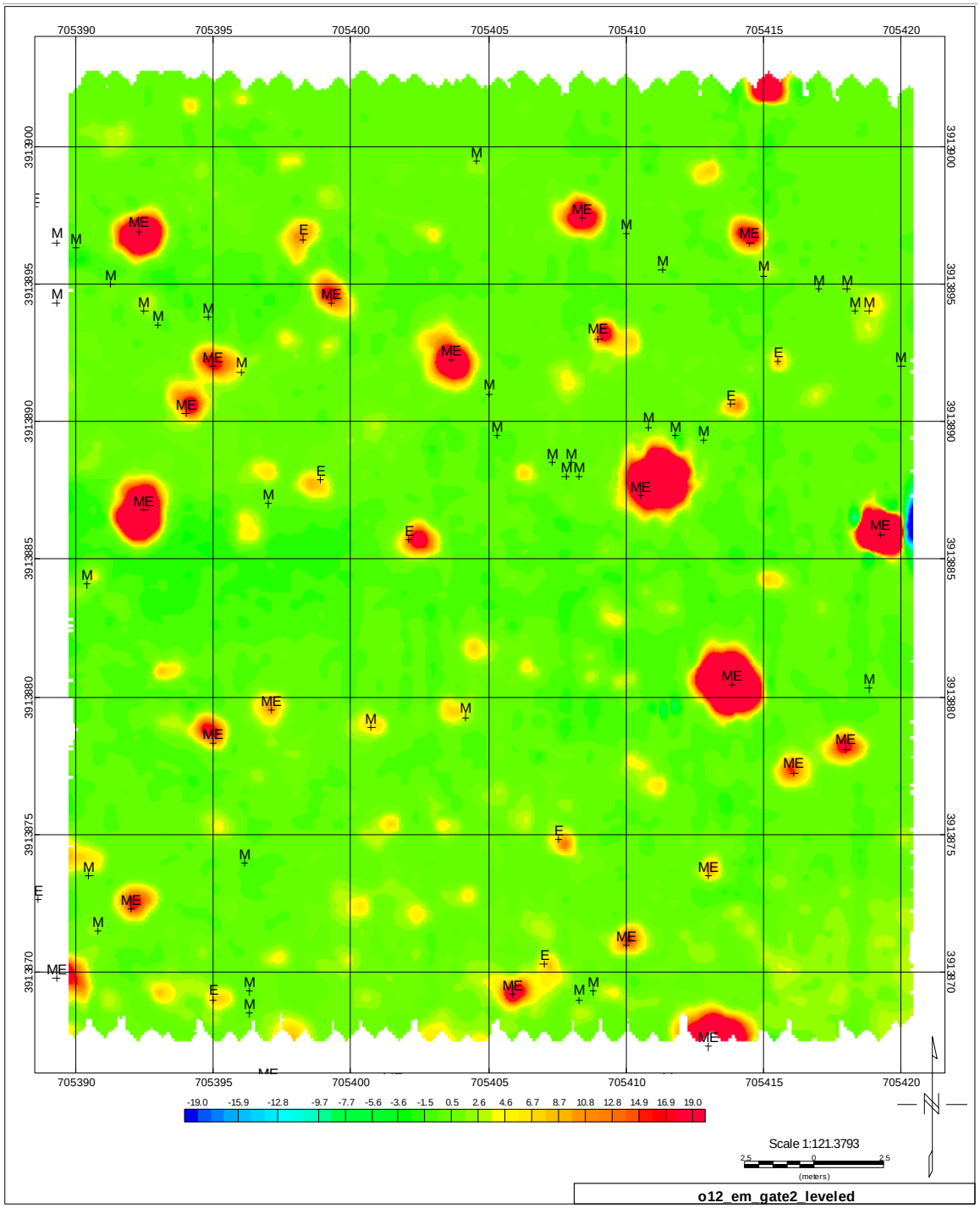
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:227.5862
2.5
0
2.5
5
(meters)
o10_o11_mag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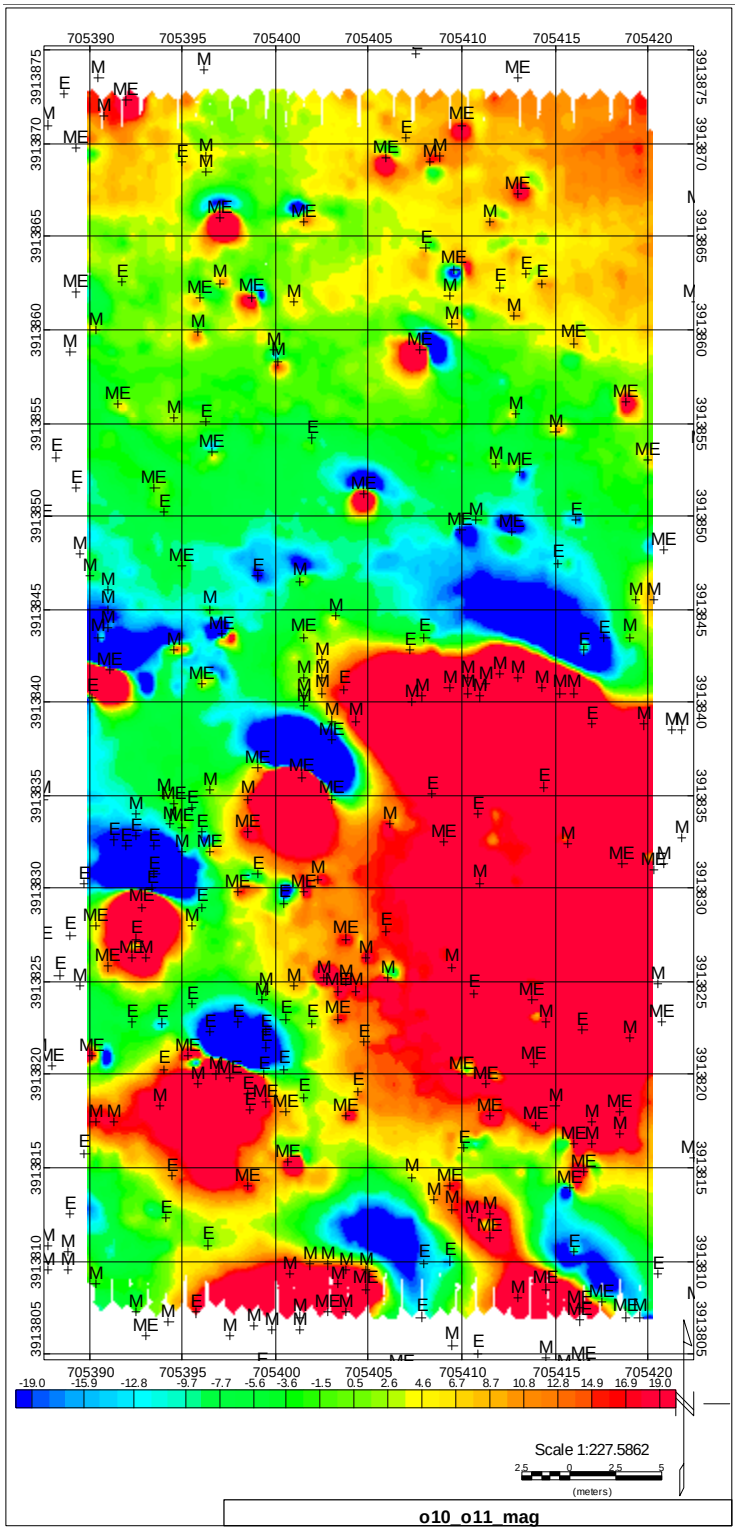
Scale 1:121.3793
2.5 0 2.5
(meters)
o12_em_gate2_leveled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-9.7
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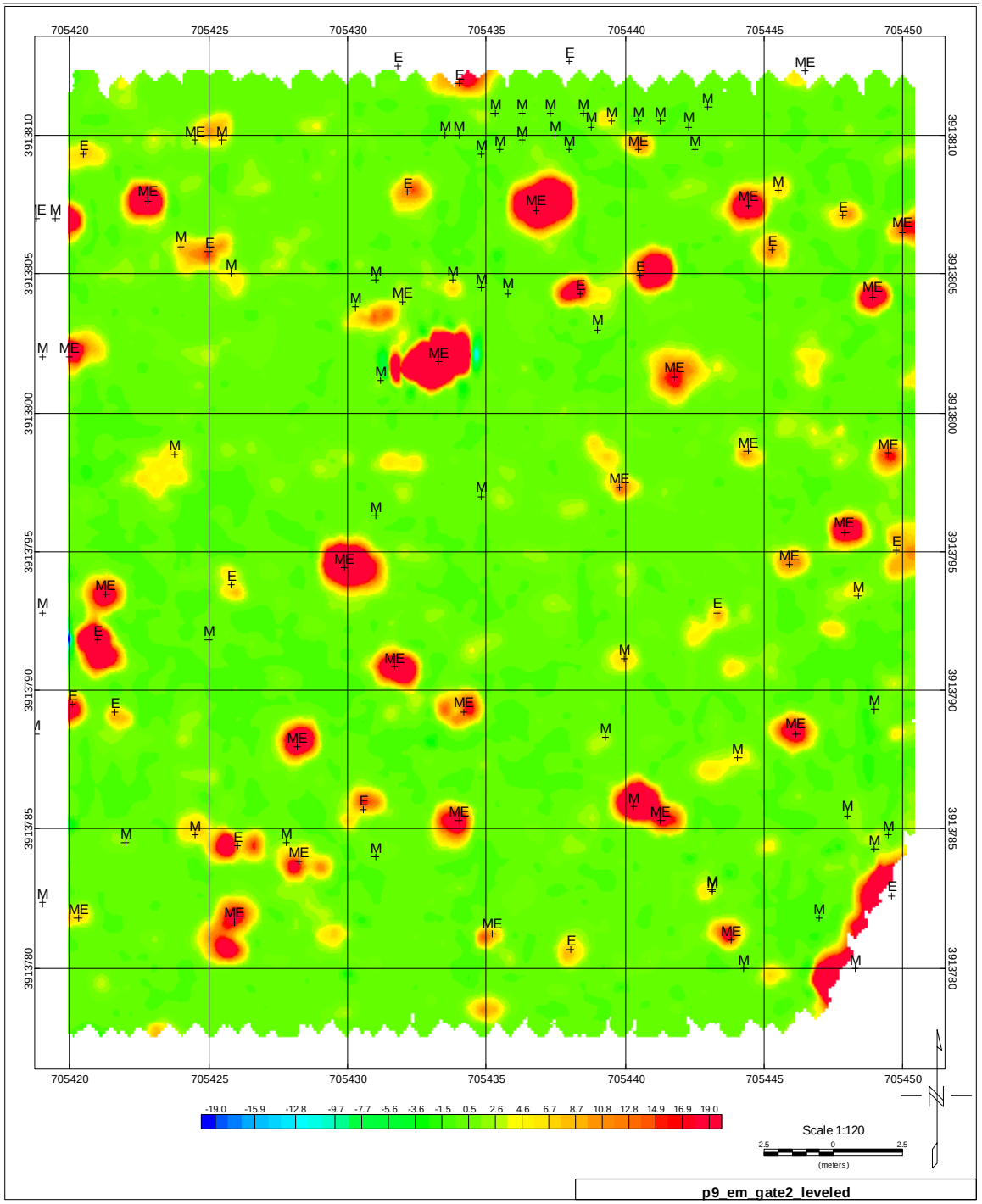
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:227.5862
2.5
0
2.5
5
(meters)
o10_o11_mag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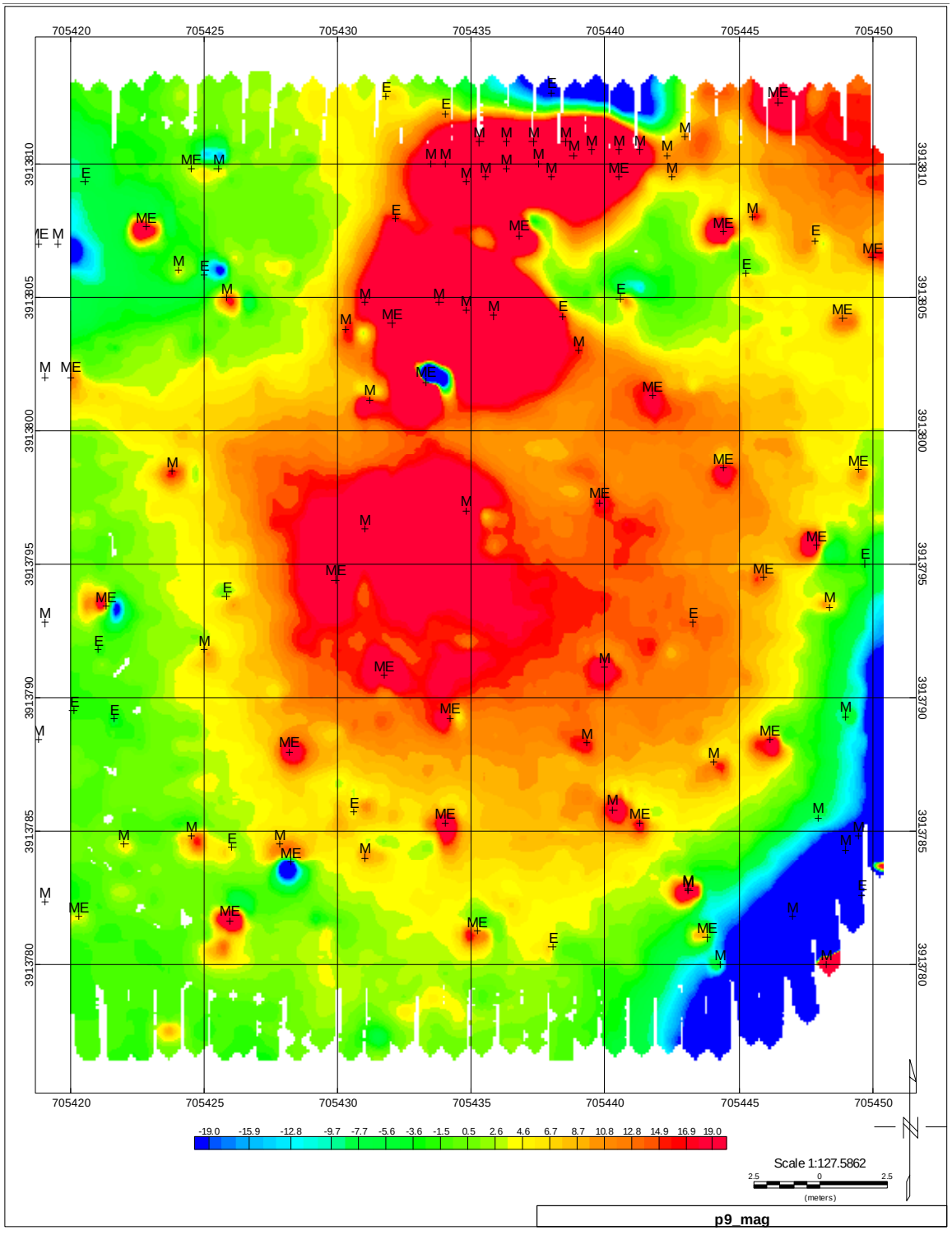
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:120
2.5 0 2.5
(meters)
p9_em_gate2_leveled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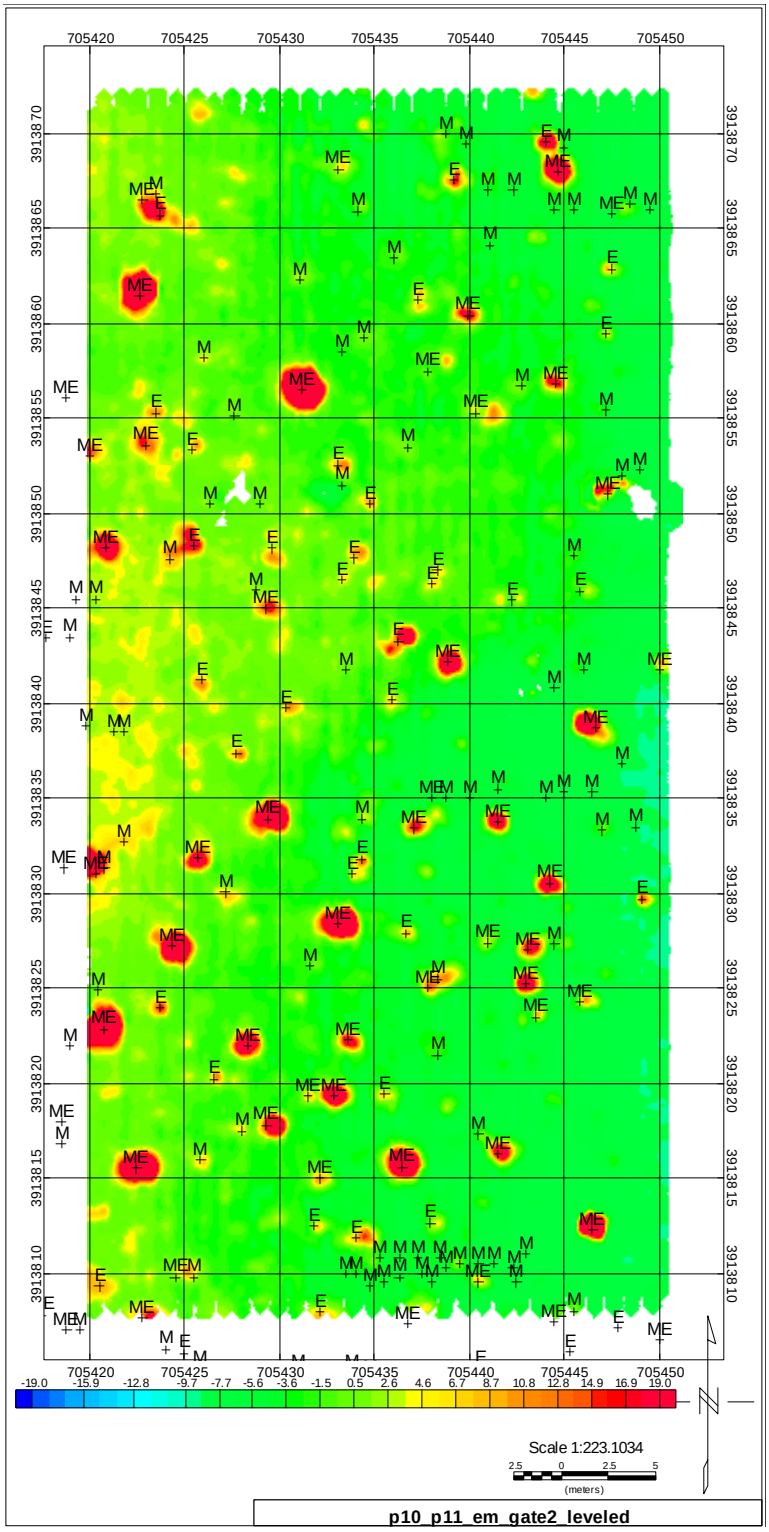
705445
705450
3913810
3913805
3913800
3913795
3913790
3913785
3913780
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:127.5862
2.5 0 2.5
(meters)
p9_mag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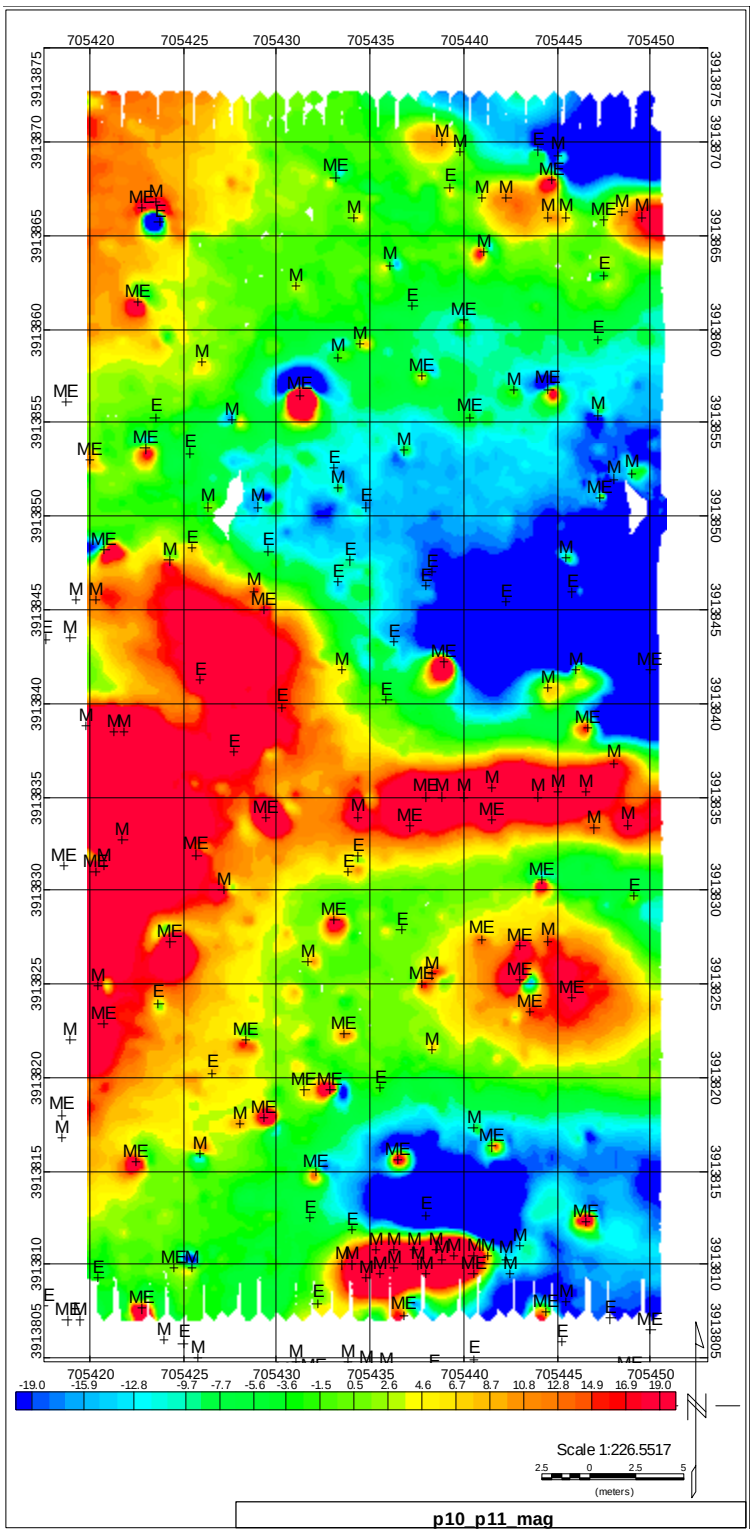
3913810
-19.0
-15.9
-12.8
-9.7
-7.7
-5.6
-3.6
-1.5
0.5
2.6
4.6
6.7
8.7
10.8
12.8
14.9
16.9
19.0
Scale 1:223.1034
2.5
0
2.5
5
(meters)
p10_p11_em_gate2_leveled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705430
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705450
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3913855
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3913840
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3913830
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3913820
3913815
3913810
3913805
-19.0 -15.9 -12.8 -9.7 -7.7 -5.6 -3.6 -1.5 0.5 2.6 4.6 6.7 8.7 10.8 12.8 14.9 16.9 19.0
Scale 1:226.5517
2.5 0 2.5 5
(meters)
p10_p11_mag